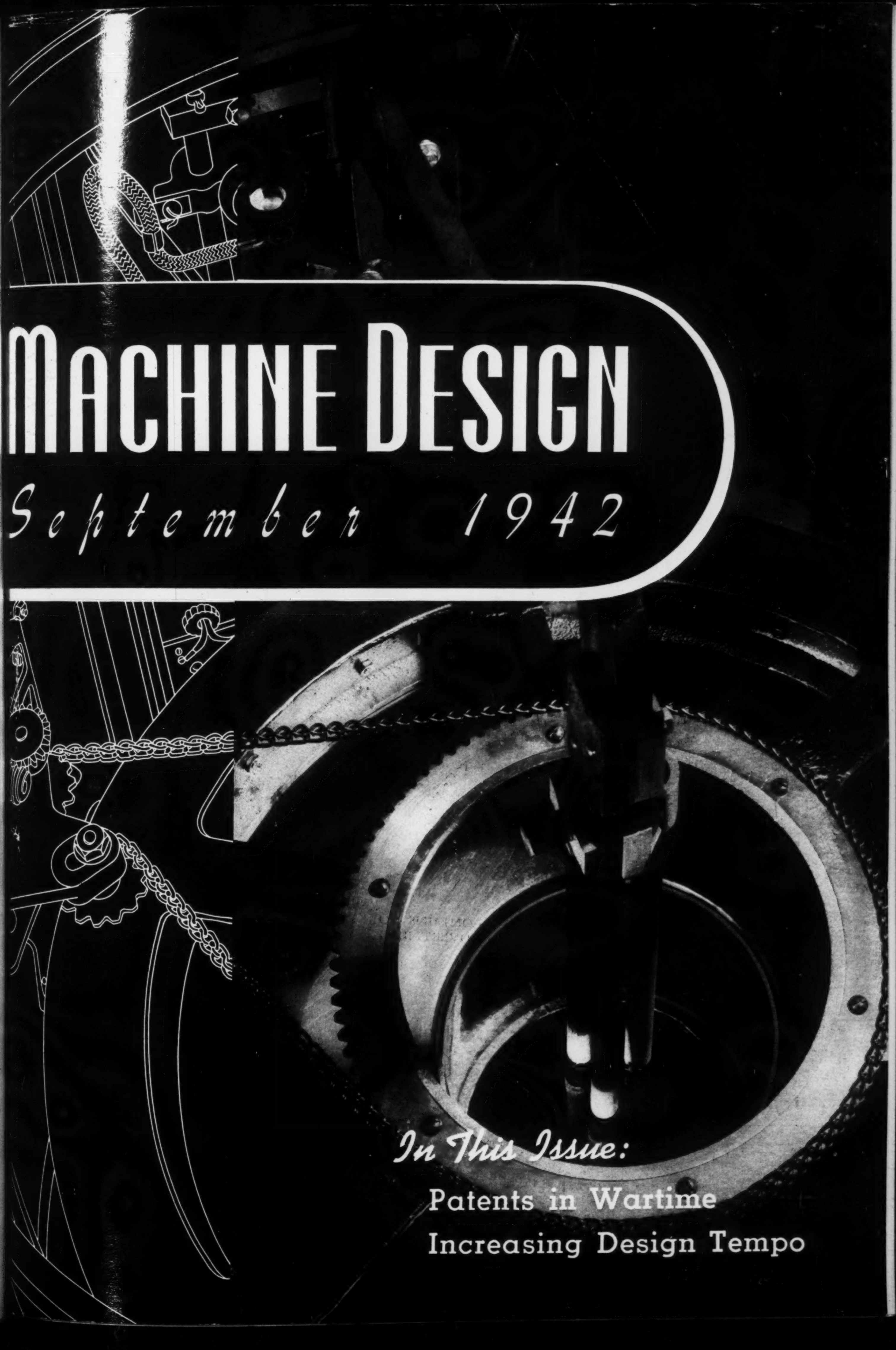

MACHINE DESIGN

September 1942

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Increasing Design Tempo

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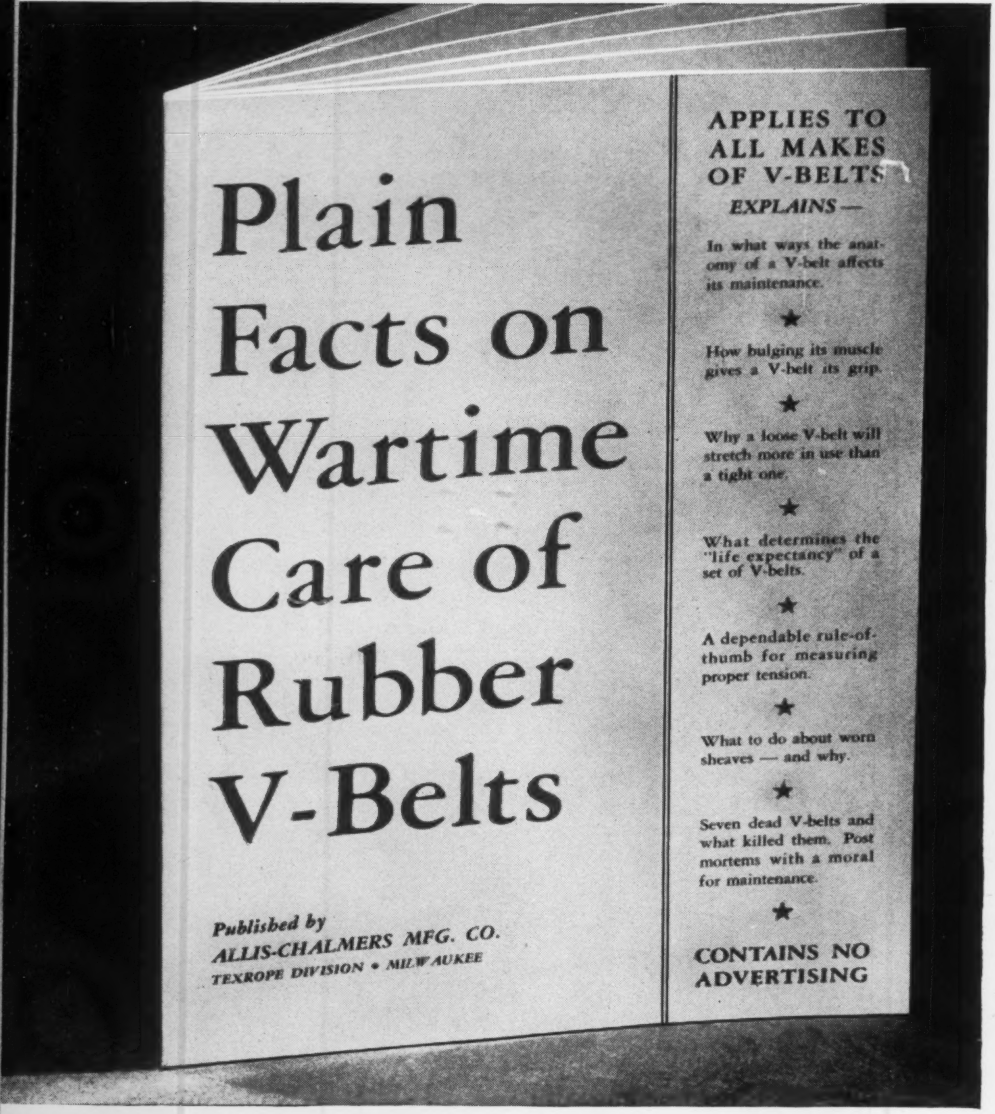
Wartime Guide to V-belt Care!



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MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

Volume 14 SEPTEMBER, 1942 Number 9

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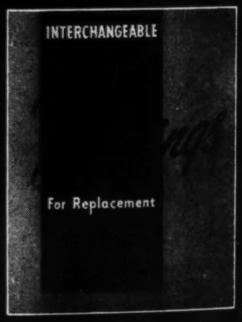

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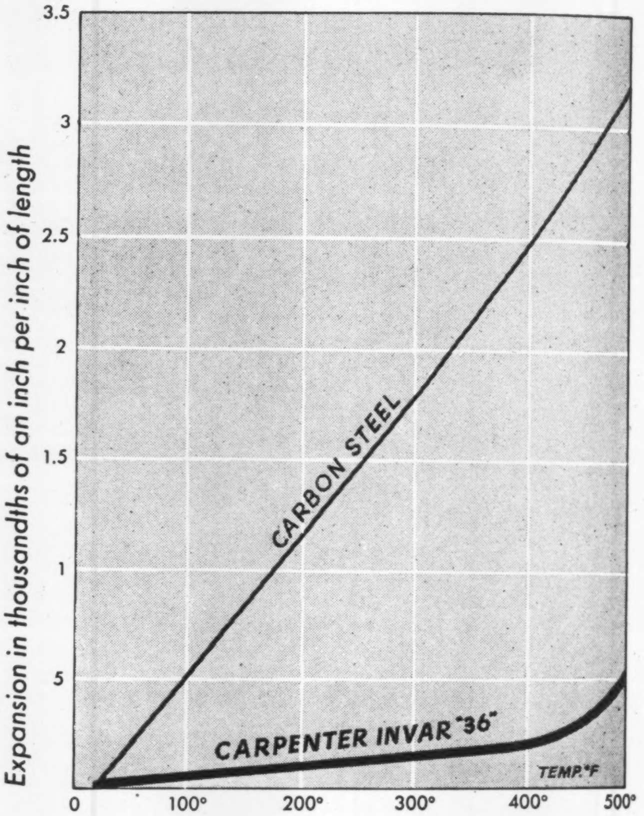

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Definite information on the spot welding of Nickel, Monel* and Inconel* was presented last October at the Annual Meeting, A.W.S., in Philadelphia. Reprints of this paper, by Wendell F. Hess† and Albert Muller‡, are now available.

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1. Recommended welding conditions for producing sound spot welds in Nickel, Monel and Inconel sheet.
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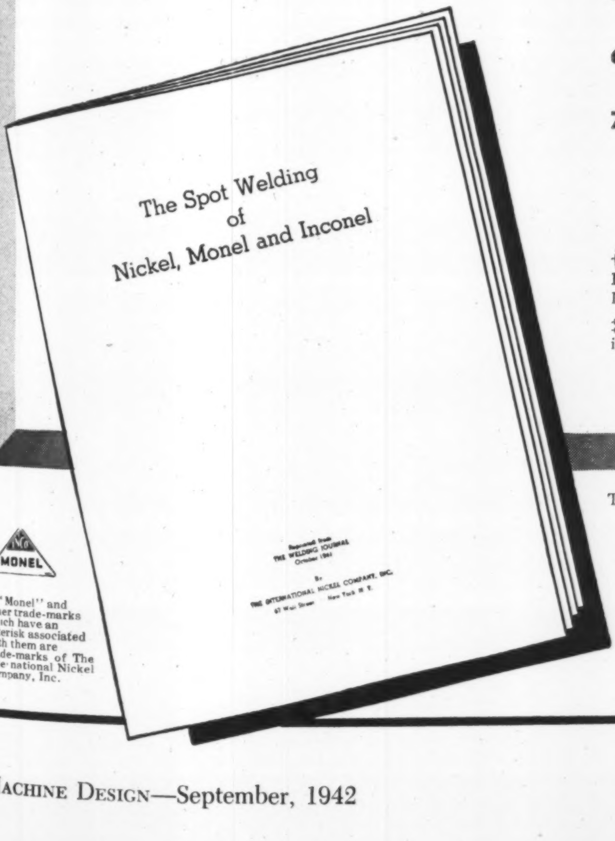
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Topics

STEEL shell cases which withstand the high pressures of gun fire, are easily loaded and ejected from the gun chamber, meet the requirements of operation in both hot and cold guns, and are free from spark hazard and obturation have been developed by Buick in cooperation with Army ordnance. These shells are in mass production and are being made in increasing quantities to effect a saving of millions of pounds of copper and other critical metals high up the list. Principal problems included development of drawing and heat-treating methods to insure proper grain flow of the steel and to produce the required yield and tensile strength of the casing in a manner consistent with the needs of volume production. This was accomplished by experimenting with one-third size model dies, applying the principles discussed in Dr. Goodier's article beginning on Page 26 of this issue.

◆

ELECTRIC motor users and specifiers can aid greatly in conserving critical materials and in helping manufacturers produce the maximum number of motors needed to win the war by selecting sizes on the basis of actual expected duty without overstress on additional safety factors. "When in doubt consider the next smaller rating" is a slogan suggested by L. A. Umansky of General Electric Co. which could be applied equally well to other commercial parts and designs. Adoption of this procedure as far as motors are concerned would also improve power factor.

◆

COLOR now identifies plastic spacers and washers to speed production. Each of ten standard sizes has its own specific color to aid in assembly and eliminate the need for mike measurements. Thicknesses vary from .001 to .02-inch with hole diameters up to 2 inches for each thickness of washer.

◆

RAPID growth of synthetics and substitutes in Germany has been accelerated by the war. As early as 1939 one-fourth of all motor vehicle transportation in the Axis countries was accomplished with synthetic or substitute fuels. To those who predict an early defeat of Hitler on the basis of fuel exhaustion, B. B. Williams, president of The Cooper-Bessemer Corp. suggests reconsideration.

◆

TO REDUCE the time required for analyzing the grain size of powder metals, Westinghouse has developed a method employing a glass tube, photocell, light bulb and milliammeter. Requiring fifteen minutes instead of eight hours formerly necessary, the specimen powder is mixed with acetone and a wetting agent. The mixture is placed in the tube and, as the particles settle, light is passed through and is measured by the photocell and indicated on the instrument. Readings at regular intervals give a curve which may be compared with known standards. Thus both the average size and relative quantities of different particles in the test specimen may be determined.

◆

CELLULOSE acetate lenses can be coated with a thin glass film without affecting the optical properties of the lenses. The development combines the advantages of both plastics and glass.

◆

FOUR new million-volt X-ray machines are being installed in vital plants to speed war production. These high-powered units will speed radiographic inspection and reduce costs because sections can be quickly inspected and better films obtained. The four plants are American Steel Foundries, Navy Yards at Norfolk and Philadelphia, and The Campbell, Wyant and Cannon Foundry Co.

◆

STANDARD specifications for machine tool wiring and electrical units developed by American Standards association and the National Machine Tool Builders association have been made mandatory by WPB. This standard besides specifying the best present practice, saves considerable time by obviating "wading" through lengthy specifications for each machine. Similar standards could be adopted for all classes of electrical machines, as well as standard symbols and diagrams as discussed in Elberty's articles in MACHINE DESIGN for April and May, 1941.

War Needs Inspire Siren Design

By Charles H. Morris

Sound Engineer
Chrysler Corporation

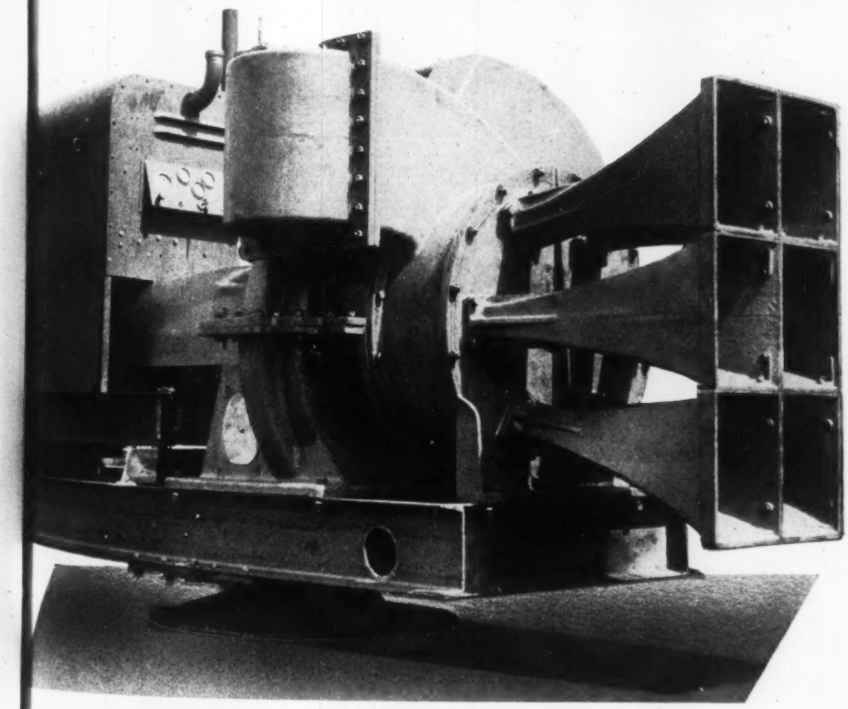


Fig. 1—Producing sound level of 170 decibels at the throats, the Victory siren has an effective coverage of two miles radius in a downtown section

WITH bombers traveling more than five miles per minute the prime consideration in air raid defense is the speed of precautionary measures. Design of an adequate alarm system is therefore of paramount importance. The Victory siren, *Fig.* 1, recently developed for air-raid warning by engineers of the Chrysler corporation and the Bell Telephone laboratories, produces the loudest continuous noise ever created by mechanical means.

Choice of the size of this unit, which was designed in accordance with requirements of the Office of Civilian Defense, was governed by the need for adequate coverage in noisy city areas. In order to be heard against the competition of city noises the necessary sound level must be in excess of 70 decibels at every point within the area to be covered. Furthermore, with the obstacles imposed by tall buildings on typical city terrain, the sound level diminishes approximately 10 decibels each time the distance from the source is doubled. This is shown by the middle curve in *Fig.* 2, which represents the performance of a powerful sounding device only slightly less intense than the new siren. Intersection of the curve with the 70-decibel dotted line occurs at 1⅝ miles from the source. Diminishing the source strength by 10 decibels cuts the effective hearing distance in half, and the area covered is only one-fourth as much.

To cover effectively the desired radius of two miles in a downtown area a sound level of approximately 140 decibels at 100 feet is necessary, as inspection of *Fig.* 2 shows. To develop this intensity the sound level at the throat of the siren must be 170 decibels, corresponding to a pressure variation approximately ten per cent of atmospheric pressure. Variation of pressure equal to one atmosphere, corresponding to 190 decibels, would involve momentary vacuum and therefore represents the loudest sound that could be produced by mechanical means in atmospheric air.

Power Requirements Limit Size

Upper limit of size for the unit was set by the physical dimensions desirable. Corresponding to a sound level of 140 decibels at 100 feet the sound power developed is close to 40 horsepower. To increase the sound level by 10 decibels the power would have to be increased ten times, because the decibel scale is proportional to the logarithm of the sound power. Thus a comparatively slight increase in noise level would entail a prohibitively large power output. Power actually absorbed, including losses, is well within the capacity of a standard automobile engine, hence the unit can be independent of other sources of power.

Sound Levels Used in Raid Warnings

Description	Sound Level (decibels)
Maximum possible in open air	190
Dangerous to hearing of unprotected ears	130-190
Very loud sound—close to aero engine and propeller	100-120
Noisy locations—factories, streets with heavy traffic, etc.	85-100
Business streets and offices, stores, etc.	70- 85
Quiet streets and offices, homes, etc.	50- 70
Unusually quiet conditions	35- 50
Seldom experienced except in soundproof rooms	15- 30
Limit of hearing sensitivity, average individual	0- 5

Shown in cross-section in *Fig.* 4, the unit comprises the siren proper or modulator, and a blower to supply compressed air. The noise is created by a high-frequency disturbance of air, achieved by means of a chopper 25 inches in diameter, *Fig.* 5, revolving with a clearance of .02-inch across the openings of six rectangular throats connecting with the horns. Compressed air, supplied by the two-stage blower at a pressure of five pounds per square inch, is introduced behind the chopper and surges out through the throats only when these are uncovered by the chopper blades. The variations in pressure thus set up in the throats cause the noise. Since the chopper revolves at a maxi-

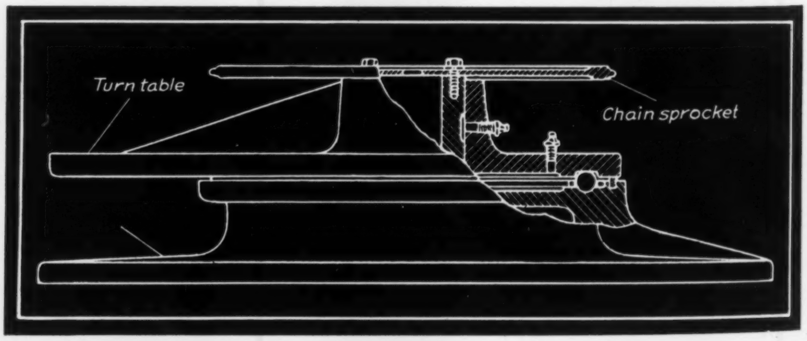
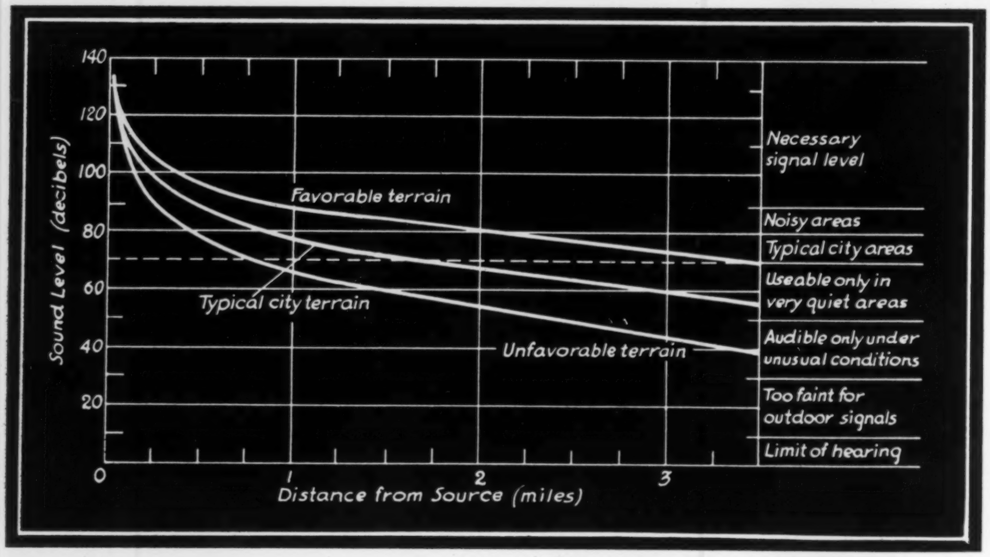


Fig. 3 — Above — Chain - driven turntable rotates on ball thrust bearing

Fig. 2 — Below — Average signal level distribution for a source strength of 135 decibels at 100 feet. Signal strengths below dotted line are not effective in city areas



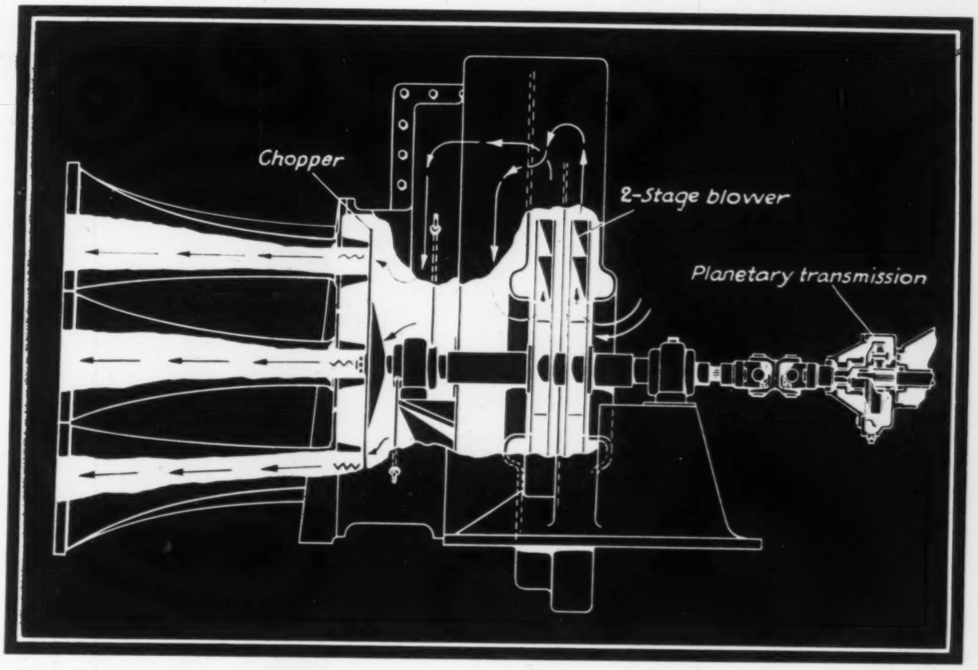


Fig. 4—Arrows show path of air through blower, chopper, throats and horns

mum speed of 4400 revolutions per minute the frequency of interruption of air flow is 440 cycles per second, a pitch close to *A* on the musical scale. The volume of air handled is 2500 cubic feet per minute and the exit velocity is 360 miles per hour.

Power to operate the blower unit is supplied by a Chrysler eight-cylinder automobile engine. Drive for the blower and modulator is through a fluid coupling unit and a planetary step-up transmission. The fluid coupling permits the engine to be started and idled without driving the siren. Radiator, 18-gallon fuel tank, ignition system, starting motor and battery are complete with the engine. The entire unit is bolted on a frame built up of 8-inch steel channel, mounted on a turntable geared to revolve once in two minutes, and may be placed on top of a building or in any other elevated position where the sound waves will have a clear channel. Power for the turntable is taken off the engine through a belt to a gearbox from which the turning mechanism is driven by a horizontal chain, *Fig.* 3.

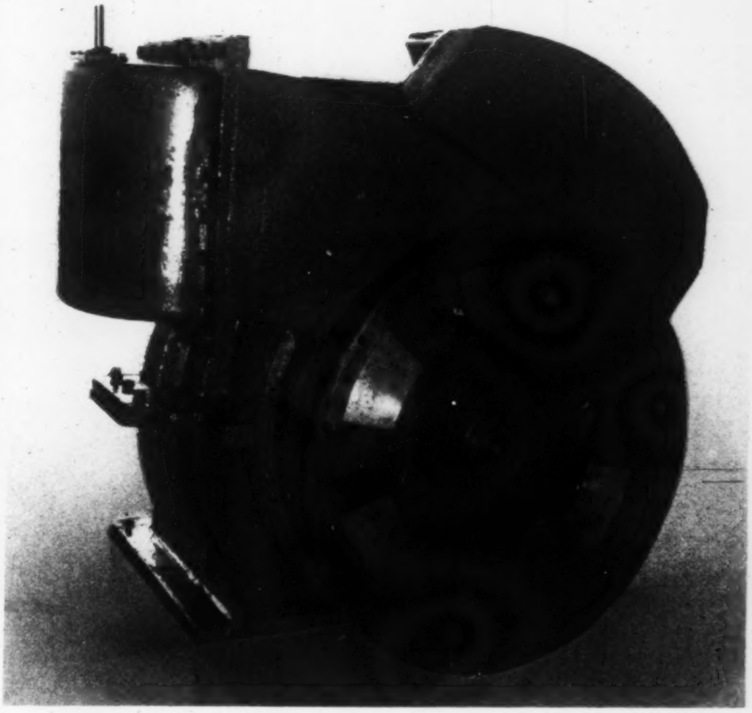


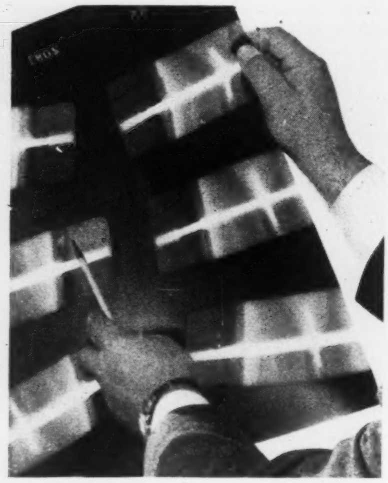
Fig. 5—Six-bladed chopper revolves across the faces of six throats, interrupting the escape of air. Duct shown at upper left carries air from blower to siren proper

Development of the siren from an experimental unit built of welded steel plates to the production model had as its goal the conservation of strategic materials. Thus cast iron has been adopted for the blower housing, chopper housing and horns while the chopper itself is of steel. The shaft carrying the impeller and chopper is supported by a double opposed roller thrust bearing at the engine end and by a ball bearing between the blower and the chopper.

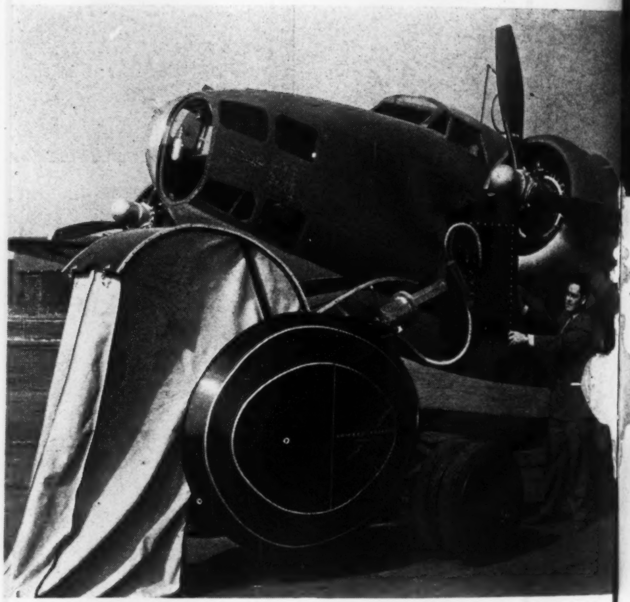
Building powerful units of this size rather than a greater number of small units also results in saving materials. Further, by concentrating sound in a narrow beam and revolving the unit, the same coverage is obtained at a saving in power and number of units compared with a stationary unit radiating equally in all directions. Dead spots are also much less likely to exist in the area covered when a revolving beam unit is employed.

Scanning the Field for

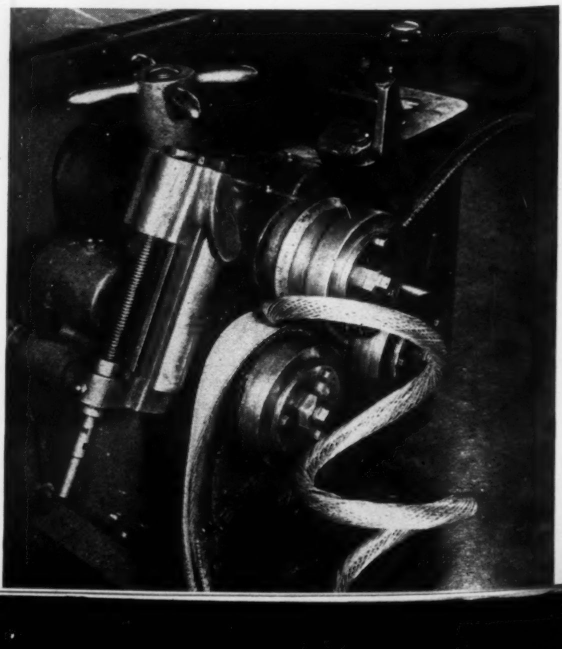
Portability of a machine often extends its application as well as increasing its service factor, thus saving vital time and critical materials for war use. An excellent example is the X-ray trailer, left, developed by Lockheed-Vega. Parts of planes damaged by enemy action or other causes may be examined on the field in a few minutes without necessity of dismantling the parts. If a prop or landing gear has suffered an internal crack, the X-ray film as shown in insert will disclose the fault, saving the plane and crew from possible loss due to defects. Power for X-raying is supplied by a towing truck. To enable the unit to reach all vital machine parts, it has a 360-degree yoke with boom and mechanism having a 16-inch stroke and a 6-foot up and down motion. The hoist is hydraulic and control of the exposure is automatic. Dark room with developing tanks is contained in the fabric enclosure.



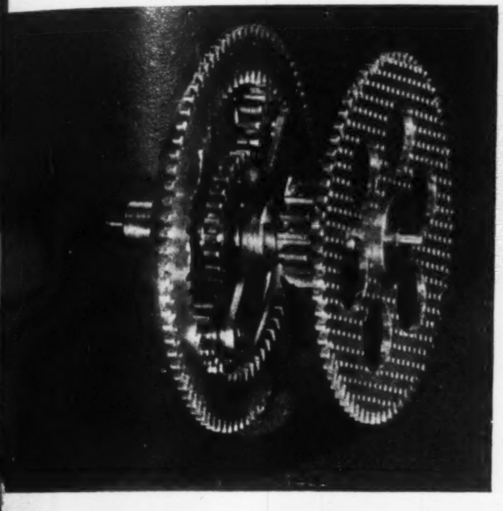
Salvage to be performed economically requires ingenuity and often involves the conversion of equipment to facilitate operations. Seldom is scrap material free from other materials which must be separated before reclamation is possible. Such was the case when The Timken Roller Bearing Co. set out to salvage rubber from scrap electric cable.

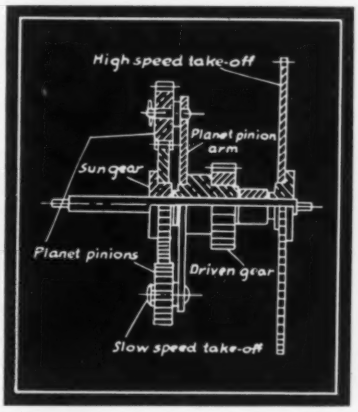


Utilizing a standard bending roll machine by replacing one of the lower wheels with a notched gripper wheel and the upper with a sharp center-flanged wheel, insulation, as shown below, is quickly removed from the cop-



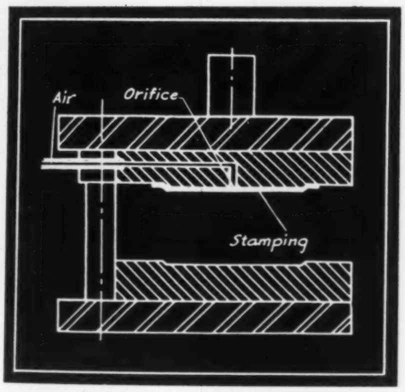
per. Varying pressures are exerted by raising or lowering the upper wheel. In this way both rubber and copper are effectively reclaimed.





Speed change without shifting gear teeth is effected in the differential unit illustrated at left for positive driving of an instrument mechanism. Designed by Esterline-Angus Co., the driven gear is a running fit on the staff and carries with it the planet pinion arm and planet pinions. These in turn mesh with both the sun gear and the internal teeth of a ring gear. The sun and the takeoff gears are fastened on the same shaft and are held stationary for the slow speed ratios of one and one-half turns of the ring gear to one turn of the driven gear.

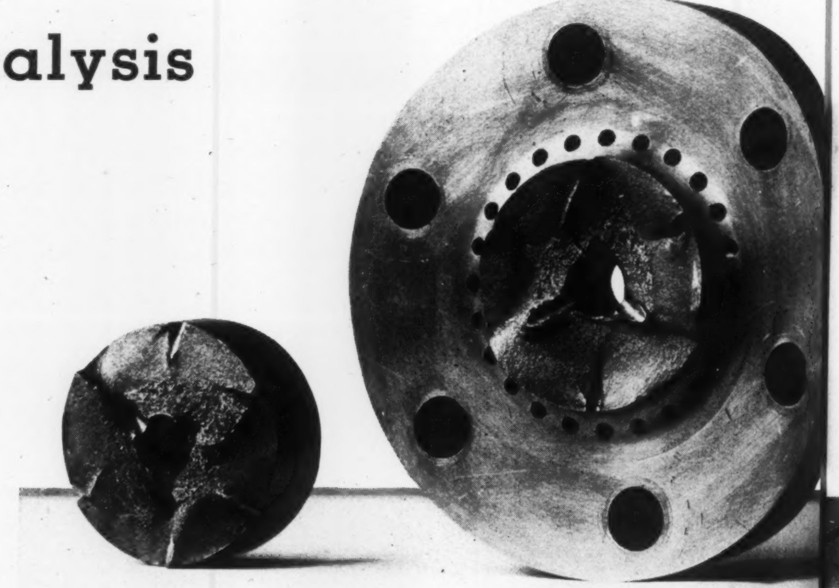
For rapid feed the slow-speed takeoff gear is permitted to turn, carrying with it the staff and the sun gear. The differential action causes the high-speed takeoff gear to revolve three times as fast as the driven gear. At the same time the ring gear may be stopped or continue to run at the same rate as when the high-speed gear was stopped.



Simplified operation resulting in increased production is a primary goal of designers of production machines. Coupled with this is the necessity for increasing automaticity and operating speeds without unduly complicating control mechanisms. An example of a simple expedient to double production on a punch press by merely incorporating an air jet in the upper die is shown at left. Applied by Westinghouse, a $1/4$-inch orifice in the upper die admits air at a pressure of 80 pounds per square inch, effecting sufficient lifting power to raise a formed aluminum part with the upper die. The principle of the inverse relation of air pressure to velocity is utilized. Escaping air between the stamping and the upper die must overcome inertia and friction, causing a reduced air pressure which results in a balance such that the stamping floats on a plane close to that of the die. A valve, timed by the crankshaft, closes the air line at the top of the stroke, allowing the part to fall from the die. In this way the time necessary to pry the part loose is obviated and production correspondingly increases without danger of scratching.

Increasing Design Tempo through Model Analysis

By J. N. Goodier
Cornell University



—*Photos Courtesy Westinghouse E. & M. Co.*

***Fig. 1**—Fatigue model for a turbo-generator part. Similarity principles do not cover fatigue phenomena. Small models give too high an endurance limit, so models should be as large as possible*

IT IS now firmly established that testing in hydraulics, aerodynamics, heat transmission and vibrations should wherever possible be based on dimensional analysis. Such analysis can reduce enormously the amount of investigation required to cover the effects of several variables, and it can establish accurate rules for the interpretation of a full-sized prototype from tests made for convenience or economy on models. In many cases the information obtainable from a small model can be applied with as much certainty as when the results of the tensile test on a small test piece are applied to a large tension member. The tensile test in fact is taken so much for granted that we do not think of it as a model test, even when drawing the conclusion that a large member will behave in the same way up to failure. Advantages of being able to interpret the behavior of models without vagueness will scarcely need emphasis whether convenience, economy of material, or economy of time is paramount. Indicative of the practical applications are the accompanying illustrations—*Fig.* 1 of the turbo-generator fatigue model[1] and *Fig.* 2 of a stress model[2] for piping layout.

Strength testing, however, has not relied extensively on models or on dimensional analysis. Frequently, it has been thought that where the elastic limit is exceeded, where the stress-strain relation is curved, where buckling occurs, or in fact where any but the simplest cases are met, no simple rules of similarity for the interpretation of model tests could be found. Fortunately this pessimistic view is not justified. Certain practical difficulties may arise, as in testing aircraft and other thin-walled construction where the scale model may require extremely thin sheet which is difficult to keep sufficiently flat; but the indications of dimensional analysis remain simple and clear.

Dimensional analyses can be developed in various ways. In the past they have been based on intuitive ideas of what similarity really means, as when similar fluid flows are described as having geometrically similar streamlines, and on the differential equations of the problem in hand. But the simplest and most systematic procedure seems to be that used by Buckingham[3]. Neither intuition nor differential equations are required. Instead, only the ability to make a complete list of the variables concerned is necessary. Conclusions are reached by two steps:

We imagine ourselves obtaining a general formula—say for a stress—which will apply to model and prototype alike. We first demand that this formula shall be correct no matter what unit system is used. If in a given case this gives one pound per square inch when the pound and the inch are used, it must give 16 ounces per square inch for the ounce and the inch. This requirement already gives the formula certain features. We then find that it contains implications as to what must happen when the size, or physical constants, of the system are changed without changing units.

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[1] From "Model Testing as Applied to Strength of Material"—R. E. Peterson, *Journal of Applied Mechanics* (*Transactions,* A.S.M.E.), paper APM-55-11, 1933.

[2] From "The Determination of the Expansion Forces in Piping by Model Test"—Harold W. Semar, *Journal of Applied Mechanics* (*Transactions,* A.S.M.E.), March, 1939.

[3] E. Buckingham—"Model Experiments and the Forms of Empirical Equations", *Transactions,* A.S.M.E., Vol. 37, Page 263, 1915. Also P. W. Bridgman—*Dimensional Analysis*, Yale University Press, 1932.

To show how the method applies in a relatively simple case, the measurement of stress on a model and its interpretation in terms of the prototype, the latter being entirely elastic, may be considered. The loads[4] (forces) are denoted by P, r_1P, r_2P, etc., where r_1, r_2, etc., are simply the ratios of the other loads to P. The geometrical dimensions are a, r'_1a, r'_2a, etc., where a is some characteristic length and r'_1, r'_2, etc., are the ratios of the other lengths to it. Including Young's modulus E and Poisson's ratio μ, and the stress σ (a particular component at a particular point x, y, z), the list of symbols are the following:

$$\sigma, x, y, z, E, \mu, P, r_1, r_2 - - - , a, r'_1, r'_2 - - - \ldots\ldots\ldots (1)$$

between which there exists one relation, the contemplated formula for σ. This formula, like the beam formula $\sigma = Mc/I$ is to apply to all cases which are covered by varying all these variables.

Only two fundamental units are required for the measurement of these quantities, for instance a unit of force and a unit of length. This being so, there is a theorem which states that it is possible to form "dimensionless products" of symbols to a number which is two less than the number of symbols[5]. In the present problem these groups are

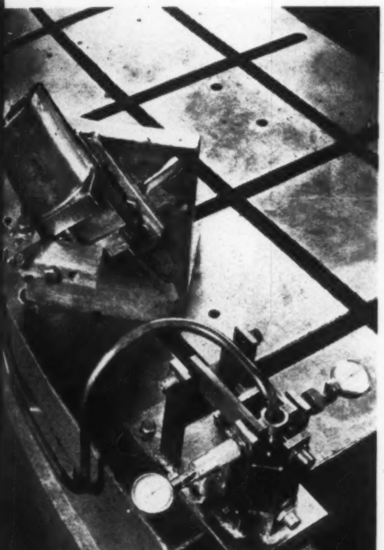

Fig. 2—Stress model for piping layout. Dimensional analysis shows that elastic stresses are independent of actual size

$$\frac{\sigma a}{P}, \frac{x}{a}, \frac{y}{a}, \frac{z}{a}, \mu, \frac{P}{Ea^2}, r_1, r_2 - - - r'_1, r'_2 - - - \ldots (2)$$

The sense of "dimensionless" here is simply that the value of a quantity so designated does not change when the individual quantities composing it are measured in a different unit system, thus altering their numerical values. An angle is dimensionless only as long as it is agreed to measure it in a definite unit, say the radian. If it is desired to consider the effect of changes to degrees or revolutions, the angle cannot be regarded as dimensionless.

If the stress formula takes the form of a relation between these dimensionless groups rather than merely a relation between the original variables, as

$$\frac{\sigma a^2}{P} = f\left(\frac{x}{a}, \frac{y}{a}, \frac{z}{a}, \mu, \frac{P}{Ea^2}, r_1, r_2, - - - r'_1, r'_2 - - -\right) \quad (3)$$

where the right-hand member denotes a function of unknown form (if it were known model tests would be unnecessary). This will be valid in all unit systems. Changing the unit system will leave the numerical value of each of the groups on the right unaltered, and they will combine as before to produce the same numerical value for $\sigma a^2/P$, which must retain this value since it is itself dimensionless. The theorem known as Buckingham's π-theorem shows that this is the *only* way of insuring that the formula shall be true in all unit systems, provided there is only *one* relation between the variables concerned.

Conditions Necessary for Similarity

Having arrived at this result simply by requiring independence of unit systems, changes of *size* represented by changes in a, and also changes in P, E and μ should be considered. Since the form of the function f in Equation 3 is not known there is virtually only one thing which can be said about it. It will retain the same value only if the groups inside it—the arguments—retain the same value. Thus, if the following ratios:

$$\frac{x}{a}, \frac{y}{a}, \frac{z}{a}, \mu, \frac{P}{Ea^2}, r_1, r_2 - - - r'_1, r'_2 - - - \ldots\ldots\ldots (4)$$

are the same for both model and prototype, then $\sigma a^2/P$ is the same for model and prototype.

Making r'_1, r'_2, etc., the same merely means geometrical similarity. Making r_1, r_2, etc., the same means an obvious similarity of load distribution. Making x/a, y/a, z/a the same means that the stress must be measured at the point on the model which corresponds to the point at which it is required to know the stress. These conditions of course are normally taken for granted, but this method of dimensional analysis, being free from such assumptions, insures that there are no unnecessary restrictions. Next μ must be made the same in both model and prototype—that is, if it matters. In beams and frames with members free of torsion and, in many cases, of stress concentration, Poisson's ratio does not affect the behavior, and could be omitted from the list of symbols at the start. Finally, P/Ea^2 must be made the same or, using the subscript m for the model, p for the prototype, the following relations exist:

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[4] Loads defined as stresses or moments can be introduced equally well.

[5] A systematic way of forming these products is given in reference in footnote 1.

$$\frac{P_m}{E_m a_m^2}=\frac{P_p}{E_p a_p^2} \quad \text{or} \quad \frac{P_m}{P_p}=\frac{E_m a_m}{E_p a_p^2} \qquad (5)$$

The load on the model must be scaled down according to this rule. There is nothing to prevent the use of a model material of different Young's modulus, if that happens to be convenient. That change is allowed for in the factor E_m/E_p.

Having thus made all the dimensionless arguments of the function the same for both model and prototype, it is possible to conclude that the value of the function itself, and therefore of $\sigma a^2/P$, will be the same for both, that is,

$$\frac{\sigma_m a_m^2}{P_m}=\frac{\sigma_p a_p^2}{P_p} \quad \text{or} \quad \sigma_p=\sigma_m\frac{P_p a_m^2}{P_m a^2_p}$$

Introducing the value that has been given to P_m/P_p, the following is obtained:

$$\sigma_p=\frac{E_p}{E_m}\sigma_m \qquad (6)$$

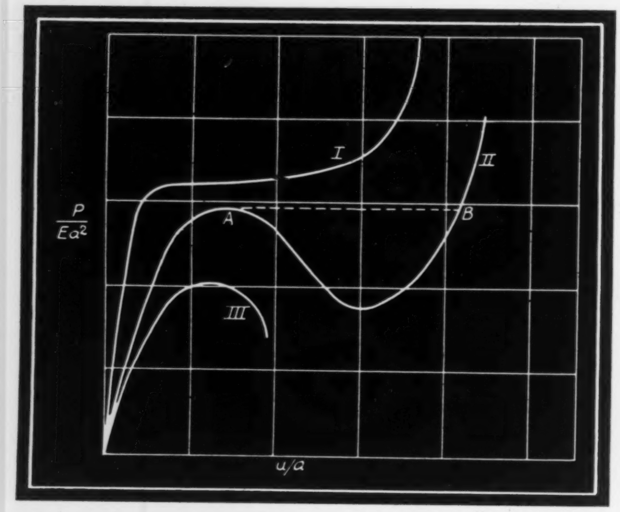

Fig. 3—Characteristic curves for a column. Curve I is for thrust, II for snap-over buckling, and III for buckling after proportional limit is exceeded

from which σ_p is calculated when σ_m has been measured.

This analysis may be extended to problems other than those of stress determination. In the determination of a deflection u, the dimensionless group u/a is used instead of $\sigma a^2/P$. In the determination of a strain-component, e itself may be used since it is dimensionless[6]. In the determination of a force R, such as a redundant bearing reaction, R/P may be used. Grouping all these problems together, the requirement that their formulas shall tell the truth no matter what unit system is used leads to the conclusion that

$$\left.\begin{aligned}
\frac{\sigma a^2}{P}&=f_1\left(\frac{x}{a},\frac{y}{a},\frac{z}{a},\mu,\frac{P}{Ea^2},r_1,r_2,---r'_1,r_2'---\right)\\
\frac{u}{a}&=f_2\left(\frac{x}{a},\frac{y}{a},\frac{z}{a},\mu,\frac{P}{Ea^2},r_1,r_2,---r'_1,r'_2---\right)\\
e&=f_3\left(\frac{x}{a},\frac{y}{a},\frac{z}{a},\mu,\frac{P}{Ea^2},r_1,r_2,---r'_1,r'_2---\right)\\
\frac{R}{P}&=f_4\left(\frac{x}{a},\frac{v}{a},\frac{z}{a},\mu,\frac{P}{Ea^2},r_1,r_2,---r'_1,r'_2---\right)
\end{aligned}\right\} \quad (7)$$

Then, just as before, the conclusion is that if a model is geometrically similar, possibly of a different elastic material with the same Poisson's ratio if that matters, and such that

$$\frac{P_m}{P_p}=\frac{E_m a_m^2}{E_p a_p^2} \qquad (8)$$

then

$$\frac{\sigma_m a_m}{P_m}=\frac{\sigma_p a_p^2}{P_p}, \quad \frac{u_m}{a_m}=\frac{u_p}{a_p}, \quad e_m=e_p, \quad \frac{R_m}{P_m}=\frac{R_p}{P_p}$$

which under the above conditions, are the same as

$$\sigma_p=\frac{E_p}{E_m}\sigma_m, \quad u_p=\frac{a_p}{a_m}u_m, \quad e_p=e_m, \quad R_p=\frac{P_p}{P_m}R_m \qquad (9)$$

Therefore the behavior of the prototype can be predicted from the measurements on the model.

Supplementary Knowledge Extends Conclusions

This dimensional analysis was not limited to small displacements—that is displacements too small to affect such things as the moment arms of the loads. But in many problems such as our ordinary problems of uniform or nonuniform beams, stress concentration, and so on, the displacements are small. As soon as this limitation is introduced (thus excluding buckling or beam columns from consideration, i.e., beams under simultaneous lateral load and axial compression) use can be made of the supplementary knowledge that the principle of superposition is valid. This comes from the linearity of the fundamental differential equations and boundary conditions of the theory of elasticity for *small* displacements. It is known then that doubling the loads will double all stresses, strains, displacements and reactions, and in general that there is simple proportionality between the stresses, etc., and the loads. This means that $\sigma a^2/P$ in Equation 7 must be independent of P, as must R/P, and that u/a and e must vary directly with P. Thus the group P/Ea^2 must not affect the value of the functions f_1 and f_4, and it must appear as a simple factor in f_2 and f_3. The other arguments of these functions are made the same for both model and prototype as before. Then

$$\frac{\sigma a^2}{P}=k_1, \quad \frac{u}{a}=k_2\frac{P}{Ea^2}, \quad e=k_3\frac{P}{Ea^2}, \quad \frac{R}{P}=k_4 \qquad (10)$$

where k_1, k_2, k_3, k_4 will be constants, the same for both model and structure whatever the loadings may be.

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[6] As ordinarily measured, e.g., in inches per inch or centimeters per centimeter, but could be measured in centimeters per inch, thus introducing a special unit of strain. It happens that there is no advantage in contemplating such new units, so strain is made "dimensionless".

The load is scaled down for the model in proportion to the square of the length scale, $P_m/a_m^2 = P_p/a_p^2$, and it follows that

$$\sigma_p=\sigma_m, \quad u_p=\frac{a_pE_m}{a_mE_p}u_m, \quad e_p=\frac{E_m}{E_p}e_m, \quad R_p=\frac{P_p}{P_m}R_m$$

These relations are in accordance with a commonly held view of what similarity means in a stress model. It is worth noting, however, that this view is too restrictive here. Since the relations in Equation 10 hold with the same constants k_1---k_4 for all members of the similar set, all the model is needed for is to determine k_1---k_4. This can be done, for k_1, for instance, by measuring the σ due to any load P. Of course it is better to do this by using several different loads and plotting σa^2 against P, or $\sigma a^2/P$ against P/Ea^2, to determine k_1.

By a simple extension of this analysis it may be shown that mere size as distinct from shape cannot have any effect on stress concentration as long as there is no influence of the grain structure. In fatigue, however, size effect is important[7] and the conclusion is that something besides the mere magnitude of the stress is significant. The stress which can be calculated or measured is in any case merely the average over a large number of grains, not the true stress in or about the individual grain.

Provides for Load Separation

The principle of superposition often makes possible the separation of different kinds of load, as pressure loads from inertia loads in engines, so that each can be studied separately. Such a point may seem fairly obvious, yet it is a fact that models have been built with undue effort and expense through too close attention to similarity and too little to superposition.

In many cases also, strict geometrical similarity may be dispensed with without loss of exactness. In simple trusses only the areas, not the individual dimensions of cross sections are significant. When there is simple bending the proper moment of inertia, and when there is simple torsion, the proper torsional rigidity may be provided without regard to shape.

Going back to the relations in Equation 9 which are satisfied when the conditions in Equation 8 have been fulfilled, the fact that smallness of displacements was not necessary to their derivation means that they are true even when the displacements are not small. They apply to flexible springs, to beam columns, and in fact to buckling. They are limited only by the assumption of proportionality of stress and strain.

Users of charts relating dimensionless groups of terms are sometimes impressed by the awkwardness of thinking in terms of such groups rather than in terms of single physical quantities. This disadvantage is usually outweighed, however, by the great advantage that dimensionless plotting gives the behavior of a whole set of similar systems on a single curve. Supposing, for instance, that it is desirable to represent the nonlinear deflections of a geometrically similar set of flexible springs under a given type of load. One of the springs may be taken and the deflections u measured, corresponding to several values of the load P. If u is plotted against P a different curve is obtained for each different size of spring or different material. On the other hand if u/a is plotted against P/Ea^2 the *same* curve is obtained for all members of the set. The function f_2 in Equation 7 has the same form for all the springs, and a given value of P/Ea^2 will produce the same value of u/a no matter which member of the set it refers to.

Curve I in *Fig.* 3 represents the kind of curve that is obtained by testing a flexible column under thrust. The flat part of the curve corresponds to buckling occurring before the proportional limit is exceeded. It occurs for a certain value of P/Ea^2. Since the same curve is obtained from a larger or smaller but geometrically similar column, buckling in a prototype is related to buckling in a model by the condition

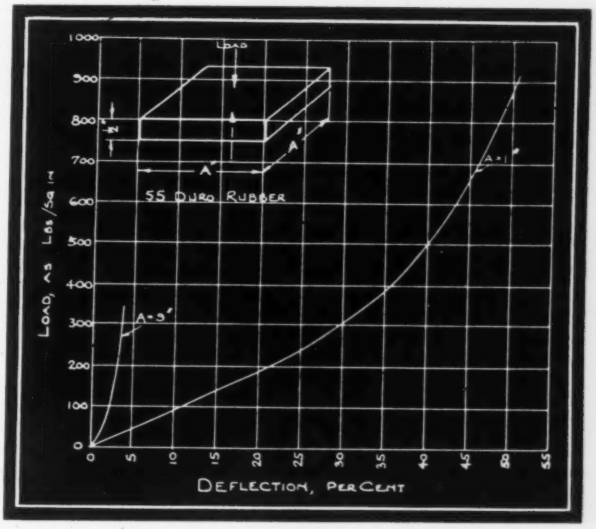

Fig. 4—Curve of stress versus per cent deflection of compressed rubber block

$$\frac{P_p}{E_pa_p^2}=\frac{P_m}{E_ma_m^2} \quad \text{or} \quad P_p=\frac{E_pa_p^2}{E_ma_m^2}P_m$$

In fact buckling is simply a special event which occurs during loading, and it occurs for a definite value of P/Ea^2 for all similar structures, just as turbulence is a special event which occurs during acceleration of a fluid motion at a definite value of the Reynolds number for a whole set of pipe-fluid systems.

Curve II in *Fig.* 3 may be obtained where a snap-over or "oil-can" type of buckling occurs. The downward sloping part of the curve represents unstable positions, and when the maximum point A is reached there is a sudden jump to some point B on the rising, stable part of the curve. Here again the buckling point A occurs at a value of P/Ea^2 which is the same for a similar system.

(*Concluded on Page* 138)

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[7] R. E. Peterson—"Model Testing as Applied to Strength of Materials", *Transactions*, A.S.M.E., Paper APM-55-11, 1933.

Which Thermostat?

Part II—Pressure Types

By John W. Greve

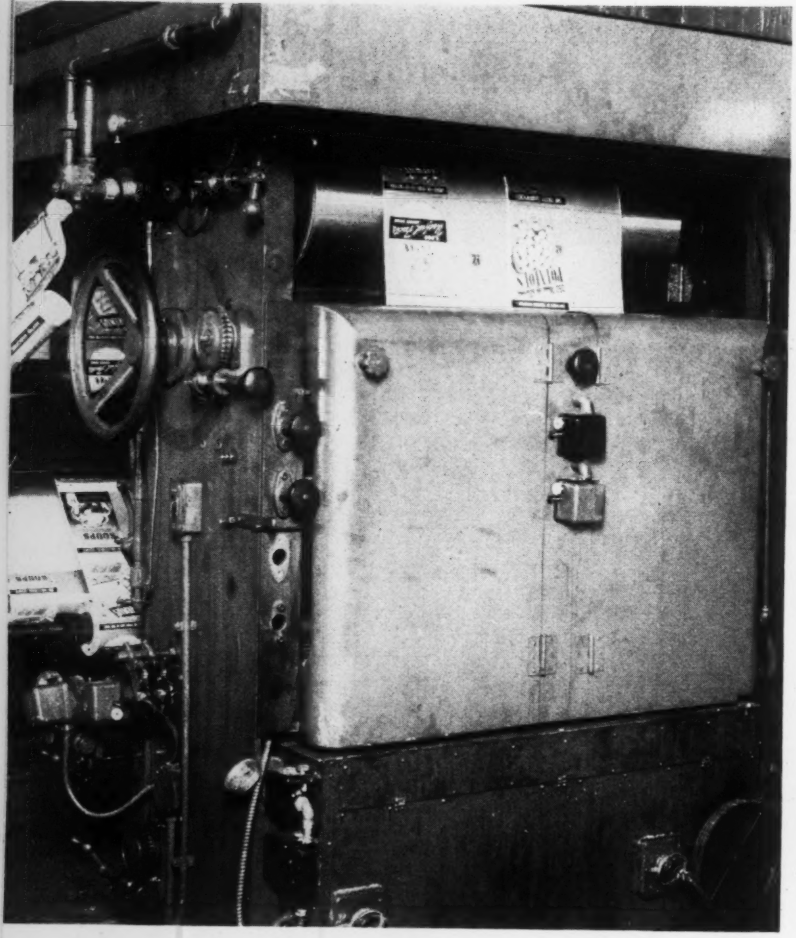

Fig. 1—Six thermostats keep thermoplastic material at a constant temperature of 280 degrees Fahr. in this paper coating machine

PRESSURE-TYPE temperature controls have specific advantages over other types of thermal-sensitive units in that they may be self-contained, have sufficient power to operate valves, relays, pens or other mechanisms and have wide temperature response. These are usually selected over pyrometers when initial costs are a determining factor, particularly in the lower ranges.

Actually pressure gages applied to temperature measurement, thermometer systems consist of a bulb for the thermal-sensitive element, a capillary tube and an actuating member, the whole system filled with a medium responsive to temperature changes in the range desired and with the characteristics needed. Actuating members are spiral, helix, Bourdon tube, bellows, diaphragm, or other special shapes. Capillary tubing is restricted as to length and material depending on the filling medium used. Special thermometers, however, may combine the bulb and actuating members without using a capillary tube. Thermostats used in automobile radiators are typical.

Four classes of thermometers are recognized, based upon the type of fill used. They are:

1. Liquid filled
2. Vapor pressure
3. Gas filled
4. Mercury filled.

Shown in *Fig.* 1 is an application of liquid-filled thermostats to a thermoplastic coating machine. This type is based upon volumetric expansion due to temperature change of a liquid other than mercury. It has a straight-line function depending on the thermal coefficient of expansion of the liquid used.

Thermal coefficients for a few liquids are shown in TABLE I which also includes maximum operating temperatures and boiling points. Corrections must be made for change in volume and also for any change in coefficient with the temperature, if appreciable. Movement of actuating member is definite and positive even though small. Xylene and alcohol are the most common liquids used. Copper, brass, stainless steel, plain steel, monel, or other materials may be employed for the bulb and tubing.

Liquid-filled thermometers have operating ranges between -150 and 750 degrees Fahr., depending upon the filling medium. Uniform scale, wide range of operating temperatures, unlimited force, and small bulbs are advantages of this system. Their limitations, however, include low sensitivity requiring large bulbs with respect to operating member if sensitivity for small temperature changes is necessary. Also, length of capillary tubing is restricted to 25 feet unless the instrument is fully compensated. This type of compensation is indicated in *Fig. 2B* and is provided by an oppositely wound spiral with a parallel capillary tube having a dead end at the bulb. The system contains the same fill as the thermometer. Changes in ambient along the tube and in the case result in no movement of the measuring spiral. With this arrangement, tube length may be increased to 125 feet.

Because compensation increases the cost, it may be more satisfactory to apply a gas or vapor-tension system. Also, when capillary is long, a pyrometer as discussed in Part I of this series (M. D. August) may be preferable, especially if there is any danger of damaging the capillary tube.

Vapor-pressure thermometers, often called "hot spot" thermometers are more simply constructed and do not have the disadvantages of the liquid-filled types. Because the vapor pressure is determined by the highest temperature along the bulb, compensation for ambient is not necessary. In fact this is the only form of thermometer that does not require compensation. Also, it has the fastest response to temperature change.

Table I

Liquid Characteristics

Liquid	Coefficient of Expansion (per F × 10^{-3})	Operating Temperature (Max. F)	Boiling Point (F)
Acetone	.825	175	133
Chloroform	.710	185	142
Ethyl alcohol	.623	210	173
Ethyl ether	.920	140	95
Glycerine	.280	350	554
Mercury	.101	1200	675
Toluene	.680	275	231
Turpentine	.540	350	311
Water	.115		212
Xylene	.635	325	284

Partially filled with a liquid, the system must be so designed that liquid-to-vapor surface is always contained within the bulb, necessitating proper size and charge. Bulb size is generally larger than for liquid filled but smaller than for gas or mercury filled. If bulb works at temperatures both above and below that surrounding the tubing and operating member, it must be sufficiently large to hold all of the liquid and part of the vapor or all of the vapor and part of the liquid. This system will not operate without a "dead spot" at ambient or cross-over temperature.

These vapor-pressure thermometers have an increasing scale which is often an advantage in that a scale may be so selected as to operate at a sufficiently wide portion of the scale and yet be operable over relatively wide temperature differences. Characteristics of typical filling mediums are shown in the vapor pressure-temperature curves in *Fig. 3*. Through the use of a chart of this type, the best medium for a given temperature and pressure range is easily determined.

Table II

Characteristics of Gases

Gas	Critical Temp. (C)	Specific Heat° (Cal./g)	Viscosity† (micropoises)	Coefficient of Expansion‡ (per C)
Air	—141	.2404	171	.003665
Carbon dioxide	31.1	.1989	139	.003724
Hydrogen	—240	3.389	84	.003664
Nitrogen	—147	.2477	164	.003672
Oxygen	—119	.2178	189	.003672

°At constant pressure and 15 degrees Cent.
†At 0 degrees Cent.
‡At 76 cm. of mercury.

Gas-filled thermometers are slowest in response and require the largest bulbs of any of the four classes. Also, because they operate at lower pressures and smaller changes in pressure, they are more affected by changes in the system, particularly friction in the linkage of the operating member. These are used where a wide operating range is required.

An inert gas, usually nitrogen, is employed. The coefficients of expansion do not vary appreciably for different gases, although specific heat and viscosity which affect response are widely different. In this respect hydrogen has advantage over nitrogen. Nitrogen, however, is more available and cheaper and is therefore more universally applied. Operating temperatures must be considered and cannot go beyond the critical temperature of the gas. These factors are compared, for the more usual gases, in Table II.

Compensation, where required, is usually accomplished by case compensation as shown in *Fig. 2A* by selecting a bimetal to cancel movements due to ambient temperatures. Ambient temperature effects on capillary are minimized through the use of a sufficiently large bulb to reduce the error.

Mercury-filled thermometers are most expensive of the four groups. For accuracy, they must be fully compensated like the liquid-filled group as shown in *Fig. 2B*. Steel or stainless bulb, capillary and spiral are necessary. Response is reduced because it is a function of mercury viscosity and capillary friction. Although this type has many advantages for industrial use in that it operates at high pressures up to 1200 degrees Fahr., its cost is relatively high. When capillary tubes employed in a system are longer than 200 feet,

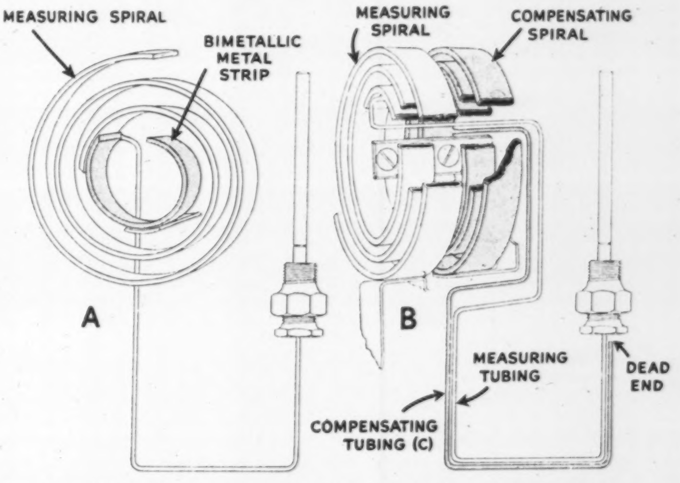

Fig. 2—Methods to compensate for ambient temperatures. At A is shown a bimetallic strip, compensating for effect of ambient on measuring spiral. At B is a duplicate system except that it dead-ends at bulb and is reversed to operating parts to compensate fully for all ambient temperature effects

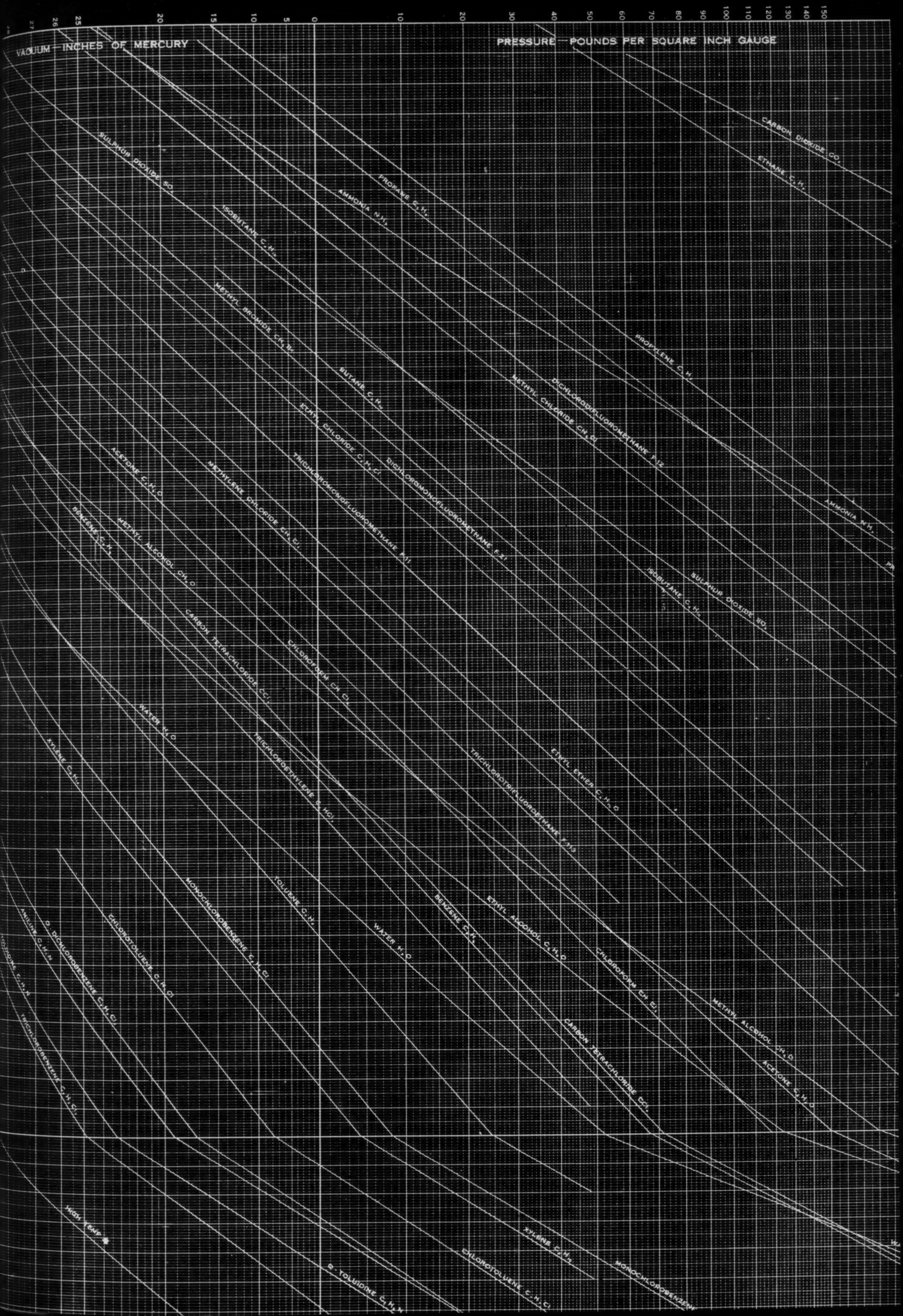
VACUUM—INCHES OF MERCURY
PRESSURE—POUNDS PER SQUARE INCH GAUGE
27
26
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
CARBON DIOXIDE CO_2
ETHANE C_2H_6
PROPANE C_3H_8
AMMONIA NH_3
SULPHUR DIOXIDE SO_2
ISOBUTANE C_4H_{10}
METHYL BROMIDE CH_3Br
PROPYLENE C_3H_6
DICHLORODIFLUOROMETHANE F-12
METHYL CHLORIDE CH_3Cl
BUTANE C_4H_{10}
ETHYL CHLORIDE C_2H_5Cl
DICHLOROMONOFLUOROMETHANE F-21
TRICHLOROMONOFLUOROMETHANE F-11
METHYLENE CHLORIDE CH_2Cl_2
ACETONE C_3H_6O
METHYL ALCOHOL CH_4O
BENZENE C_6H_6
AMMONIA NH_3
ISOBUTANE C_4H_{10}
SULPHUR DIOXIDE SO_2
CARBON TETRACHLORIDE CCl_4
CHLOROFORM $CHCl_3$
WATER H_2O
TRICHLOROETHYLENE C_2HCl_3
XYLENE C_8H_{10}
ETHYL ETHER $C_4H_{10}O$
TRICHLOROTRIFLUOROETHANE F-113
TOLUENE C_7H_8
MONOCHLOROBENZENE C_6H_5Cl
BENZENE C_6H_6
WATER H_2O
ETHYL ALCOHOL C_2H_6O
CHLOROFORM $CHCl_3$
METHYL ALCOHOL CH_4O
ACETONE C_3H_6O
CARBON TETRACHLORIDE CCl_4
CHLOROTOLUENE C_7H_7Cl
O DICHLOROBENZENE $C_6H_4Cl_2$
ANILINE C_6H_7N
O TOLUIDINE C_7H_9N
TRICHLOROBENZENE $C_6H_3Cl_3$
HIGH TEMP
XYLENE C_8H_{10}
CHLOROTOLUENE C_7H_7Cl
MONOCHLOROBENZENE
O TOLUIDINE C_7H_9N

Table III

Characteristics of Thermometers

Class	Filling Material	Scale Increments	Relative Cost†	Relative Response†	Bulb Size†	Maximum Tube Length (ft.)	Temperature Range Low (F)	High (F)	Operating Pressures (psi)	Bulb Elevation Correction	Ambient Temperature Correction
1.........	Liquid	Uniform	3	2	1	150*	−150	750	300-500	Yes	Yes
2.........	Vapor-pressure	Increasing	2	1	2	300	− 25	650	150-600	Yes	No
3.........	Gas	Uniform	1	4	4	500	−200	800	300-500	No	Yes
4.........	Mercury	Uniform	4	3	3	150*	− 40	1200	400-1200	Yes	Yes

*When fully compensated, otherwise maximum length is 25 feet.

†Figure one representing lowest cost, fastest response, smallest bulb.

cost approaches that of a potentiometer.

Comparisons of the four basic types of fills are listed in Table III. This quickly summarizes the outstanding features and is useful in preliminary selections.

Bulb elevation with respect to the operating member is of little consequence in the mercury-filled and liquid-filled types. The hydrostatic pressure exerted by the column in the capillary, however, should be taken into account in calibrating the instrument. Because these instruments work at high pressures, this is of little importance in these groups, especially the mercury types. For gas-filled instruments, this head is not measurable. In the vapor-tension group correction is required and may involve complications. Where operating temperatures are both above and below the ambient, problems are involved in that the hydrostatic head changes its direction of force. For this particular set of conditions it is not advisable to use more than two-foot differential in elevation.

Speed of response for all classes often can be improved by reducing the mass of metal, by increasing the ratio between the bulb surface and its volume, by using a metal with a higher rate of heat transfer, or by placing the bulb in a more critical spot where the temperature is a better sample of the change in the properties being controlled. These considerations in addition to selecting the best fill whether gas, vapor, liquid or mercury with their characteristic responses, previously discussed, should yield a well-designed unit.

When gas temperatures are to be measured, radiating fins increase the contact surface and consequently improve the speed of response. Long bulbs or even helical bulbs give averaging temperatures provided the vapor-pressure type is not used. Bulbs are usually seamless tubing and of a material with the best strength and heat transfer characteristics that will not be affected chemically by any corrosive elements present. Because of the present materials situation, 41-30 aircraft steel is used for mercury-filled bulbs and cold-rolled steel for liquid or gas-filled bulbs. Capillary tubing for mercury fill is stainless and bronze for liquid or gas fill.

Although protective wells for bulbs increase thermal lag they are recommended for applications where the chemical action of the product would affect the bulb, where the bulb would contaminate the product or where it might be necessary to remove the bulb for inspection without disturbing the product.

Fig. 3—Preceding page—Vapor pressure-temperature curves for typical filling mediums

Cleanliness, roundness and uniformity of the bore in capillary tubing is a prime requisite to insure accurate calibration of the instrument. Tubing of ordinary low-carbon steel having a wall thickness of 30 to 40 per cent of the outside diameter is capable of withstanding pressures well above 10,000 pounds per square inch. Manufacturers have standardized on capillary sizes of stainless type 347 to reduce the critical elements, particularly chromium and nickel, and the amount of material for stock. Tubing for low-pressure work is of thinner walls, requiring a protective sheathing.

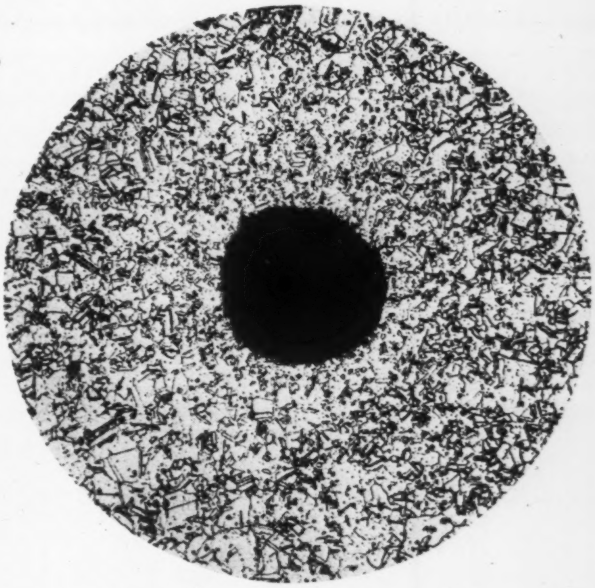

Fig. 4—Photomicrograph of 18-8 stainless capillary tube with .007-inch bore. Magnification 100 diameters

Lengths up to 250 feet are available and inside diameters vary from .02 to .005-inch. The smaller diameters are used for long capillary tubes to keep down the size of bulb required but should only be applied where necessary because response lags considerably for smaller tubes. A photomicrograph of a present standard stainless capillary tube is shown in *Fig.* 4.

Operating members may take many forms depending on the pressure available, stroke required and mechanical linkage. These include simple diaphragm, bellows

(*Concluded on Page* 140)

Fig. 9—Photographing microscope capable of enlargements up to 2000 diameters

Wartime Metallurgy Conserves Strategic Materials

Part II—Crystalline Structure

By R. E. Orton and W. F. Carter

Acme Steel Co., Chicago

PHYSICAL testing with its significance as a measure of the characteristics of a material was discussed in the preceding article of this series. The remainder of the articles will cover the modification of materials by heat treatment, mechanical work, addition of alloys, etc., to attain the qualities measured by these physical tests. A necessary prelude to such a discussion is a close examination into the nature of metals. Many, in practical work, feel they can ill afford the time for the study of theory. They desire a more direct attack. Often such a procedure is necessary, but frequently it results in misapplication. During the present emergency, when materials are vital and all-important, the nation cannot afford such waste.

Designers have a further reason to review this theory. It is the connecting link between stress analysis and the strength of materials because it explains why a metal is strong or why it fails.

Usually the fundamental theory of an engineering subject is not as complicated as it would first appear, and the study of hardening of ferrous metals is no exception. The basic theory is relatively simple, the complexities lying in the controversies over details. Knowledge of the metallic structure is learned through indirect analysis by observation of phenomena that may only be explained by "such and such" a structure, rather than by observation of the structure itself. This leads to a series of working hypotheses. Review of the theory will be simplified by the acceptance of these working hypotheses as facts, and the ignoring of the controversial points where they have no particular bearing on the end results.

Unquestionably, the fundamentals of hardening lie in the crystalline structure of metal. This is true, first, because of the direct effect of alterations and disturbances in the structure in strengthening the material and, second, in the case of ferrous metals, in the change in the solubility for a number of the alloying elements accompanying a change in structure induced by a change in temperature.

It is axiomatic that the atoms of all solid materials are arranged either in a definite pattern or at random. Where a definite pattern exists the structure is "crystalline." When the atoms have a random arrangement the structure is "amorphous".

Considering the structure of the hypothetical simple crystalline form illustrated by *Fig.* 10, this might be termed a "simple cubic" arrangement. Atoms are located at the corner points of adjoining cubes. The lines connecting the atoms are to give a three-dimen-

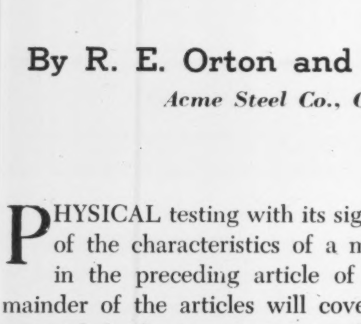

Fig. 10 — Hypothetical cubic structure. The atomic planes are characteristic of the crystalline structure

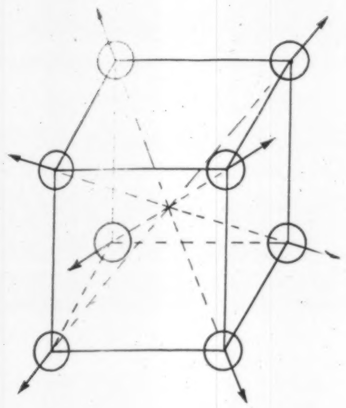

Fig. 11—Elemental atomic cube under triaxial tension. Failure would be by rupture of the atomic bonds

sional effect to the drawing, having no real existence. It should be appreciated that, while the usual metallic crystal is microscopic in size, it is vast compared to the atomic spacing. Even relatively small (ASTM Size 8) ferrous crystals may extend in all directions for over 100,000 cubes or "lattice spaces". In other words, *Fig.* 10 represents only a tiny portion of a crystal.

It was stated in the first article of this series that a brittle fracture is due to failure of cohesive bonds between the atoms. In *Fig.* 11 an elemental cube of eight atoms is shown with each atom equally loaded and in directions radial from the center of the cube. Such a condition is secured by equal triaxial stress, i.e., stress equal in all directions. With this loading the spacing between the atoms is increased and there is no tendency to slide one atomic layer on the other. When the spacing has reached some critical value the atomic bonds will be ruptured, giving rise to a brittle fracture.

In *Fig.* 12 forces are applied parallel to the atomic layers. The tendency is to slide one layer of atoms upon the other without materially increasing the distance between the atoms. Distortion of the space lattice is the effect rather than rupture. If carried far enough a permanent slip will occur along one or a number of these "atomic planes" without destruction of the atomic bonds. The action will leave a distorted structure adjacent to these "slip planes". The outward manifestation of this slip is plastic deformation. If carried far enough bonds will eventually be ruptured but the failure will exhibit high ductility.

Simple Structure Gives Ductility

From the above it is apparent that the component of a randomly directed force parallel to the layers of atoms would cause a ductile failure, and that the component perpendicular to the layers would tend to cause brittle failures. Atomic layers or planes in *Fig.* 10 may be formed in many directions, horizontal, vertical, diagonal, etc., so that a *single* load cannot be applied in any direction that will not permit slip on some plane. This simple atomic structure affords high ductility.

In a more complex atomic structure, atomic slip planes cannot be so easily drawn because of the lower degree of symmetry. Slip will not readily occur and therefore the material will be harder and less ductile. An example is the intermetallic compound of copper and aluminum, $CuAl_2$, having a "tetragonal" lattice and a hardness of 300 brinell, although aluminum itself is about 25 and copper about 45.

In the case of a distorted structure such as that produced adjacent to slip planes, atomic planes will be warped and will interfere with ready slip, the interference depending upon the degree of the warpage. This is the explanation of the work hardening of metals.

It is reasonable to assume that no material change is made in the inherent cohesive strength of any particular metal, regardless of the alloy content, heat treatment, or mechanical work. That is, the atomic bond remains unchanged. Manifestly then, all hardening phenomena must result from some alteration or interference with the lattice structure so as to cause an increase in the slip or shear strength.

Introduction of a foreign atom into the system of *Fig.* 10 would call for a different spacing than that for the native atoms, producing a disturbance in the lattice structure. This would cause a warpage of atomic planes through and near this point which would interfere with the slip, strengthening the metal locally.

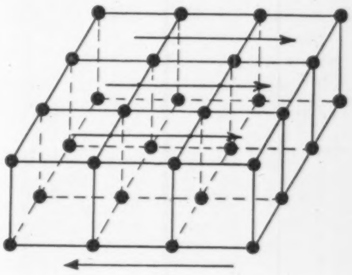

Fig. 12 — When loading is in shear and parallel to layers, the tendency is to fail by sliding of atomic layers

Therefore, this foreign atom has "keyed" the atomic layers in this region. If there are enough of these foreign atoms distributed throughout the mass of the metal, every layer would be keyed to some extent, increasing the strength as a whole. The material would also be more brittle, first because the ratio of slip to cohesive strength would be increased and, second, because there would be less slip available before failure in shear. Slip interference might also take the form of a group of atoms such as a molecule or group of molecules of a metallic compound. They would also act as a key, increasing the strength and brittleness.

Why atoms of some materials arrange themselves in definite patterns has never been satisfactorily explained. In the liquid state the atoms move about with more or less freedom. As the material congeals they take up their proper positions around some initial point or "nucleus". If there were but one nucleus there would be but one crystal extending clear to the walls of the enclosing structure. Under carefully controlled conditions it is possible to produce very large crystals of some materials. However, in the usual case there are many points from which nucleation starts, so that a great many crystals are in process of forming at any one time.

While the atomic pattern is the same at each of these nuclei, adjacent crystals will not necessarily be orientated the same, in fact they will almost invariably be inclined with respect to each other. Any particular crystal will grow then until its growth is interfered with through meeting neighbor crystals, or restricted by the sides of the containing vessel. The result is a crystal, perfect insofar as internal structure is concerned but having an imperfect boundary. Such crystals are the so-called "grains" of which metals are comprised.

While atoms are too small to be seen, the crystalline grains—consisting as they do of a large number of atoms—may be seen readily with a suitable microscope. A modern instrument equipped with means for photographing is illustrated in *Fig.* 9. The crystals are not seen as a whole, but in cross section. In brief, the process of microscopic examination is as follows:

A section is cut through the specimen, its surface ground to a fine finish and polished on special metallographic polishing wheels. Because the action of polishing disturbs the position of the atoms at and near the surface, etching reagents are employed to remove this disturbed layer, leaving exposed the undisturbed crystalline structure.

Amount of Etching Affects Appearance

Appearance of specimen depends upon extent of etching. If etching is just sufficient to remove distorted layer, each grain surface will be smooth enough to reflect a good portion of light back into the microscope. At the boundaries the etch leaves a slight valley, scattering light rays so that only a small portion enters microscope. As a result the grain is outlined by a dark threadlike line. *Fig.* 13 is a typical photomicrograph of this type for a relatively pure metal.

Heavier etching cuts into crystal structure, exposing atomic planes which then act as reflecting planes. Owing to the fact that crystals are differently oriented these planes are at different angles. From one crystal a large amount of light is reflected into microscope, from others varying amounts. The result is shown in *Fig.* 14. There is no inherent difference between light and dark grains, they are simply differently oriented. Rotating the specimen slightly will change the angle of the light, altering the intensity of illumination reflected from each grain. Clews such as these constitute the elements of fact from which the theory of the crystalline structure of metals has been developed.

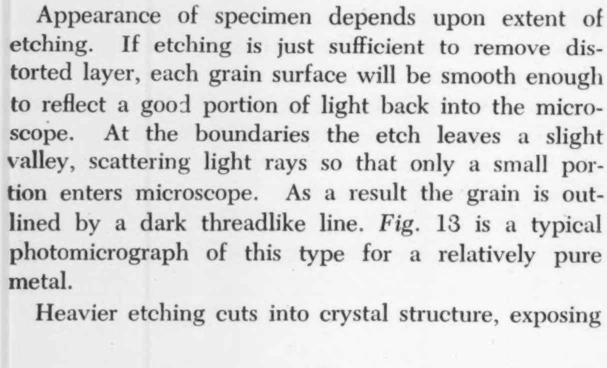

Fig. 13—Characteristic pattern of a lightly etched, low-carbon steel. Magnification, 100 diameters

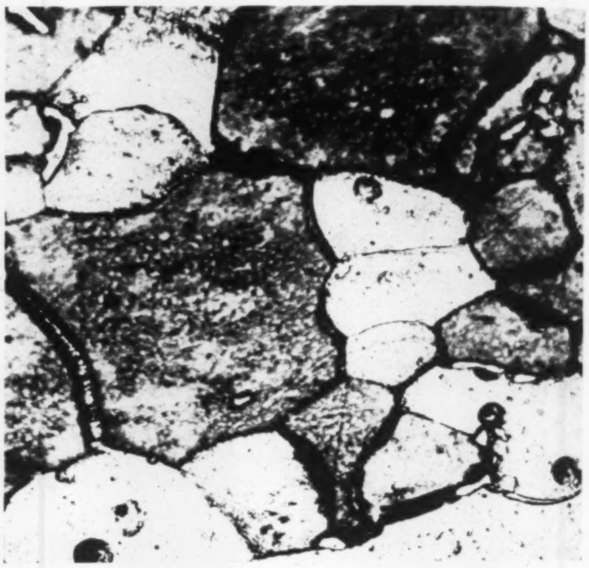

Fig. 14—Low-carbon steel of Fig. 13 with a heavier etch to bring out grain orientation. Magnification, 100 diameters

As has been pointed out, the physical qualities of a crystal vary with direction. This would appear to be a contradiction to the observed fact that metals, as a whole, do not have pronounced directional effects, excluding the effects of inclusions such as slag in wrought iron, etc. The answer to this paradox is that, even though dealing with a minute portion of material, a large number of grains is involved. For example, on an average grain size (ASTM 6) a 1/16-inch cube would contain over 50,000 crystal grains. While each crystal has its own directional effect the direction varies from one to the other, so that taken over any reasonably finite region the average qualities are obtained thereby giving "statistical isotropy". It is this statistical effect that makes it possible to apply the reasoning of elastic theory, which is based on the assumption of perfect isotropy and homogeneity, to this heterogeneous collection of minute elements that is termed a metal.

Having examined the slip along atomic planes within a crystalline grain that occurs when metal is stressed beyond its yield point, the question arises: What happens when this slip has proceeded to the boundary? There it will have to change its direction to suit the inclination of the atomic planes of the adjoining grain. This new direction may not be so unfavorably oriented with regard to the stress as the first, and therefore a higher stress value will be required to continue the slip in this neighboring grain. It should be noted that slip failure will be through a grain, and not around it. The irregular nature of the boundary makes slippage impossible at this junction surface. This, plus the early interference to the propagation of slip beyond the boundary of a small grain, is responsible for the strengthening effect of a fine-grain structure.

Effect of Structure on Fatigue

In the case of fatigue stress there is, however, an influence in the opposite direction. At points of high and local stress concentration the slip may proceed across a coarse grain and out of the reach of high stress concentration, whereas in the case of a small grain the boundary may be met while still within this region. The stress may then be sufficient to propagate across the boundary with the possibility of fracture of a number of grains and, thereby, greater danger of failure. To sum up, it would appear that the fine-grained structure resists better the spread of a crack, but that the coarse-grained structure better resists the initiating of a crack.

The profound effects of the crystalline structure of metals upon their physical characteristics is apparent. As an example, ingot iron, a soft ferrous metal with no alloying elements except impurities, may have its ultimate strength and yield increased respectively by as much as 50 per cent and 75 per cent by nothing more than a simple heat treatment to produce a finer grain than that originally present. The details of such treatment will become apparent later in the discussion.

Considering how temperature and mechanical treatment affect the grain size there are, first, usually a great multitude of points in a solidifying mass of metal from which crystals may be initiated as cooling progresses. The tendency to initiate a crystal varies widely at different points. The faster heat is extracted the greater the tendency toward nucleation at all of these points. Therefore, if the material is cooled slowly nucleation will be induced at only a relatively few points, and crystal growth will be permitted at such points with relatively little hindrance. Such treatment then, produces a coarse granular structure. If, on the other hand, the material is cooled rapidly, nucleation is induced at a large number of points and crystal propagation from each point is quickly interfered with by neighboring crystals. Such treatment then, produces a relatively fine grain structure.

At certain temperature levels, in ferrous metals in particular, grain "growth" will occur. At these temperatures the influence of lattice structure is sufficiently reduced to permit one crystal to absorb another by changing the atomic orientation of the second to suit its own. As will be discussed later, there are many factors affecting this temperature level and the rate of growth.

Mechanical work will affect the grain structure differently at high temperatures than at low. If the temperature is high enough, fragmentation of the crystals by hot-work action will be followed by reformation of the atomic bonds and there will be no resultant distortion of the space lattice. Instead large crystals will be broken into small, that is, a coarse-grained structure into a fine. There is a temperature level below which the atomic bonds will not readily reform. This temperature is also the level above which crystal growth will normally occur. The art of hot work is to continue mechanical work to, but not below, this temperature.

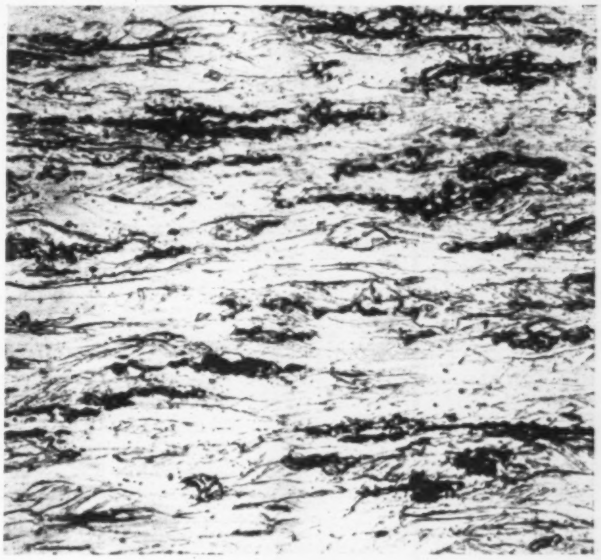

Fig. 15—Photomicrograph of cold-drawn strip steel at 100 diameters magnification

Cold work is performed below the critical temperature for the reformation of the atomic bonds. The lattice structure is greatly distorted and crystals are fragmented by slippage along atomic planes. This distorted atomic structure increases the strength by its interference with slip. The action also exhausts a portion of the available slip, increasing the brittleness. Hardening by cold work may be carried to high levels. Cold-drawn wires and thin strip may have their ultimates increased up to three times and their yield up to four times. *Fig.* 15 is a photomicrograph typical of a cold-drawn structure.

Annealing Rearranges Structure

Reorientation of the fragmented atoms of a cold-worked metal into adjoining lattice structures will occur at a temperature below that previously mentioned for the reformation of the atomic bonds. Such "strain annealing" rearranges the crystal structure and, if carried far enough, completely eliminates the cold work. This holds, of course, only insofar as the cold work does not actually destroy the atomic bonds. If the bond is de-

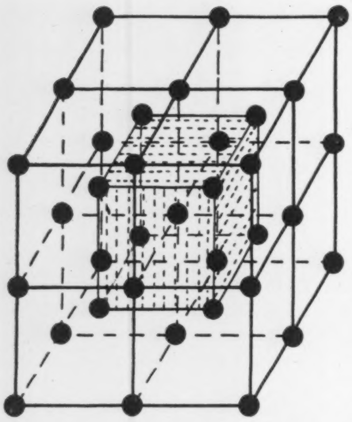

Fig. 16 — Body-centered cubic space lattice. An atom is located at each corner cnd in center of each cube

stroyed the atoms cannot be rejoined except by a forging or welding operation.

Most materials have but one atomic pattern in which they invariably crystallize. However, there are some which have two or more. To these the term "allotrope" is applied. It is not surprising to find that important changes occur in the characteristics with change to different allotropic forms. There are several well-known examples among the nonmetals. Carbon, for example, exists in the amorphous form as coke, coal, charcoal, etc.; in one crystalline form as graphite, and in another as the diamond, the hardest material known.

Outstanding among the materials exhibiting allotropy, and of particular interest to us, is iron. Under stable conditions, at room temperature, iron exists in what is known as the "alpha phase". In this phase the lattice structure is "body-centered cubic," illustrated in *Fig.* 16. This structure is obtained from that of *Fig.* 10 by placing an atom at the center of each elemental cube.

Control of Lattice Form

Under stable conditions, at high temperatures, iron exists in the "gamma" phase. Here the atomic structure is "face-centered cubic," illustrated in *Fig.* 17. Instead of an atom at the center of each cube, atoms are located in the faces. There is a critical temperature, approximately 1650 degrees Fahr. for pure iron, above which it is normal for the one lattice structure to exist and below which it is normal for the other. We can better bring out these changes by considering the solidification and subsequent cooling of pure iron.

Crystals are formed at a number of nuclei as the material solidifies. If the cooling is not too rapid these crystals will grow and form large structures known as dendrites, from their resemblance to tree branches or leaves. The various characteristics of this structure will be discussed in detail under cast steel.

As the temperature falls a point is reached where the dendritic structure granulates, that is, breaks up into smaller crystals. Recrystallization starts from a number of nuclei, followed by growth of the crystals, in a similar fashion as in the freezing and original crystallization of the metal. If the metal were held at or near this temperature, grain growth by absorption of neighboring crystals would begin and continue until reaching a large coarse-grain structure. If, however, the temperature is dropped at a reasonable rate there will be little opportunity for growth and the gamma crystalline structure will continue until the critical temperature is reached. At this point it will transform from the face-centered to the body-centered structure with accompanying recrystallization.

This forms a new grain structure. If the cooling is rapid, nucleation will be forced at many points, giving a fine grain. If the cooling is slow, grains will be initiated at only a few points and a large structure will be formed. From then on there will be no change in crystalline structure with falling temperature. As will be brought out later, however, where any appreciable quantity of foreign material is present the crystal pattern of the gamma phase will be left imprinted on the new crystal structure.

If the metal were now reheated to above the critical temperature, recrystallization into the gamma phase would occur. This cycle, alpha to gamma, gamma to alpha, may be repeated indefinitely, each recrystallization affording a new grain structure.

The preceding discussion has been concerned with pure iron. None of the commercial grades of ferrous materials can be classified as pure. It is therefore of interest to consider the effect of foreign materials. These may be present either as a "solid solution" or as a mixture. If the former, they are present in a state of "atomic dispersion", rather than molecular. The dissolved atoms may occupy position in the spaces between the solvent atoms or they may actually replace atoms of the solvent. In either case they distort the lattice structure and strengthen the solvent material.

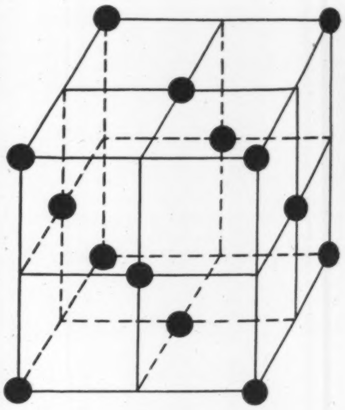

Fig. 17 — Face-centered cubic space lattice. An atom is located at each corner and in the center of each face of the cube

Atoms in solution at a sufficiently high temperature exhibit some degree of mobility. The tendency is for them to diffuse through the solvent until uniformly distributed. Thus, if a metal is held at high enough temperature for a long enough time, a homogeneous structure of dissolved material will be obtained.

We may also have nondissolved matter distributed throughout, to give an "aggregate". The matter may be so finely dispersed that it keys the lattice structure

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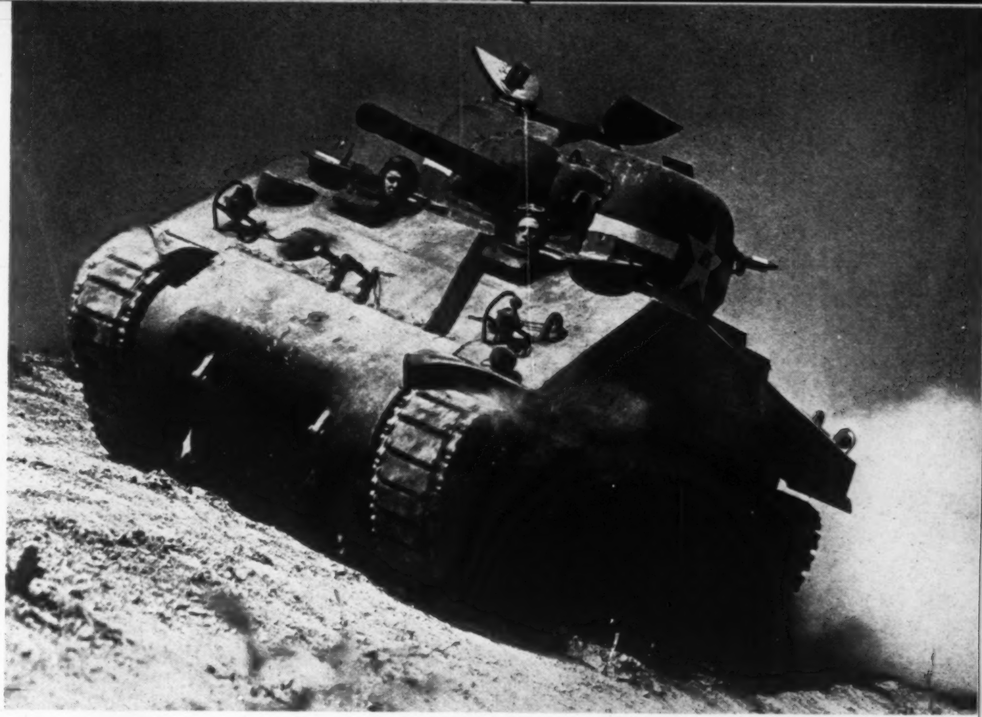
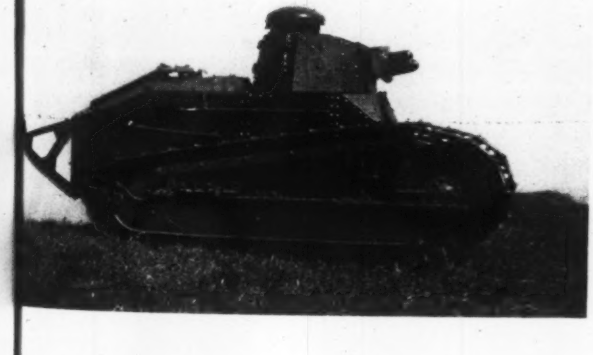


Fig. 1—Right—Late model medium tank represents accumulated design improvements

Fig. 2—Below—World war tank design is contrasted with unit shown in previous figure

By
George V. Woodling

Pending Legislation Aims at Wartime Patent Procedure



THIS is no one-man war. Inventors and designers are called upon to play a part which is essential to victory. Competing companies in peacetime now share blueprints with each other to obtain mass production on a national scale. This exchange of drawings and technical information is greatly facilitated by the existence of patent protection, because it is through the medium of patents that a sound legal basis is afforded for making such exchanges. Otherwise, in the absence of patent rights there would be a tendency for some manufacturing companies, intent on their markets after the war, to go slowly in exchanging engineering data. Companies sharing blueprints with other companies usually do so free of royalty or at a low percentage of value such, for example, as $1 for a huge airplane motor which might cost $10,000 or more—the entire motive being to supply goods to the army and navy as rapidly as possible.

In spite of all the publicized abuses of patents during the course of the war, industry as a whole should be given an award of merit for its fine spirit of cooperation in exchanging and sharing blueprints. For example, it is through this cooperation that powerful, heavily protected tanks (*Fig.* 1) are now rolling off assembly lines instead of the crude vehicles (*Fig.* 2) of earlier years.

As every designer knows, nothing created is perfect—something always appears to be wrong, and the same applies to our patent system. The point which now takes the spotlight is that some patent owners are being charged with shelving patents and stifling war production. This has been flatly denied by industry on many occasions. At any rate, in the apparent interest of preventing companies from shelving patents, two senate bills (S.2303 and S.2491) have been introduced.

The latter bill was introduced on March 30, 1942, and mainly concerns compulsory licensing which has been under public discussion for some time. In addition the bill contains many other provisions which limit the right of inventors to reap the full benefit from the exploitation of their inventions. The portion of the bill dealing with compulsory licensing provides that if the patent owner has failed for a period of three years after the issue of the patent to use the invention, or refuses

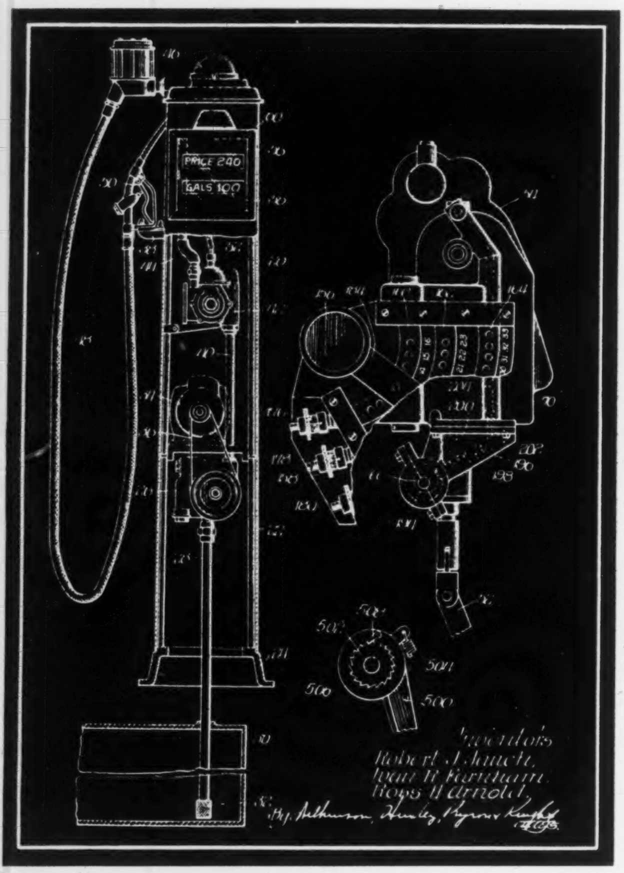


Fig. 3—Gasoline pump invention was subject of suit involving anti-trust laws which the Government lost

to allow others to use it, the Commissioner of Patents may order the inventor to make the invention available to the public by licensing others to do so, provided such failure or refusal is detrimental to the public interest. Any person at any time may present a complaint to the Commissioner of Patents alleging that there has been such a failure or refusal, after which the Commissioner shall furnish the inventor with a copy of the complaint and fix a time and place for a public hearing to determine whether or not the complaint is valid. If the Commissioner finds, after a hearing, that there has been no failure or refusal by the patentee, he shall dismiss the complaint. If the Commissioner finds otherwise, he shall prescribe the terms and conditions of a compulsory license.

Would Prohibit Restrictions on Use

A second limitation of the bill tells what the inventor cannot do in the event he negotiates a license with others. He cannot restrict (a) the extent to which any process covered by the patent may be used or the total quantity or value of machines or compositions produced under the patent; (b) the price at which any article, machine or substance may be sold; (c) the purpose for which or the manner in which any process covered by the patent on any article, machine or composition produced under the patent may be used; (d) the geographical area within which may be produced, sold or used any such article, device or material.

In addition to these restrictions the patent agreement is not supposed to contain restrictions of any kind which would tend to lessen the competition or to create a monopoly, unless such restriction is necessary to promote the progress of science or the useful arts. The bill further provides that in the event any of these restrictions are violated, the patent shall become null and void.

The foregoing restrictions involve elements which have a direct bearing upon whether or not the patent is used in violating the anti-trust laws. In the past the Government has not been too successful in winning suits involving patents which are charged to be so used and apparently these restrictions have been purposely included in the bill to make it easier for the Government's attorneys to win a case.

Complaint by Government Dismissed

Thus the patent covering the gasoline pump shown in *Fig.* 3 was the subject matter of a suit involving the anti-trust laws which the Government lost. Prior to 1932, when the patent on the pump was issued, a pump had not been developed which would automatically calculate and register both the quantities and prices of the gasoline dispensed. This patent revolutionized the gasoline pump business, and as soon as computer pumps were placed on the market they superseded all other types.

When the computer pump had become a success the patent owner granted licenses to eight other manufacturers. The indictments, among other things, charged that the patent owner and the licensees conspired "to fix, maintain and control arbitrary, artificial and noncompetitive prices for the sale of computer pumps" in interstate commerce in violation of Section 1 of the Sherman Act. In dismissing the complaint the court quoted a portion of a decision which the United States Supreme Court handed down in the case of United States *vs* General Electric company involving a suit in equity brought by the Government against the General Electric company and the Westinghouse company to enjoin them from prosecuting a plan for the distribution and sale of patented electric lamps. The portion quoted by the court reads:

> "The patentee may make and grant a license to another to make and use the patented articles, but withhold his right to sell them. The licensee in such a case acquires an interest in the articles made. But if he sells them he infringes the right of the patentee and may be held for damages and enjoined. If the patentee goes further, and licenses the selling of the article, may he limit the selling by limiting the method of sale and the price? We think he may do so, provided the conditions of sale are normally and reasonably adapted to secure pecuniary reward for the patentee's monopoly. One of the valuable elements of the exclusive right of a patentee is to acquire profit by the price at which the article is sold. The higher the price, the greater the profit, unless it is prohibitory. When the patentee licenses another to make and vend, and retains the right to make and vend on his own account, the price at which his licensee will sell will necessarily affect the price at which he can sell

his own patented goods. It would seem entirely reasonable that he should say to the licensee, 'Yes, you may make and sell the articles under my patent, but not so as to destroy the profit that I wish to obtain by making and selling them myself.'"

Another restriction of the bill (S.2491) is that every agreement or sale involving a patent right must be in writing and a copy filed with the Federal Trade Commission within thirty days after execution. Copies of the agreement are to be made available to the general public, so that any person who desires to obtain a copy may be able to do so.

Prevention of Patent Shelving Is Aim

Bill S.2303, introduced on February 13, 1942, also purports to prevent the alleged shelving of patents by giving the President broad powers over the control of patents. Section 1 of this bill would give the President for the duration of the war, the power to grant a license to any person under any patent or patents with respect to the manufacture, use or sale of any material, article, product or commodity where the expansion of facilities or capacity for such manufacture, use or sale is in the interest of national defense or of the prosecution of the war. Injunctions would be abolished. As for compensation to the patent owner, the President would have authority to fix what is described in the bill as a "reasonable fee." Section 2 of the bill gives the President still broader powers than those in Section 1, in that he would have the power or authority to acquire patents as well as to enforce licenses thereunder.

This bill is based upon the false theory that the President by the mere act of *owning* patents would automatically produce more war goods, notwithstanding the fact that under the Act of 1910 as amended July 1, 1918 the Government has the full and complete right to have manufactured for it any patent article for war purposes without the consent of the patent owner (discussed in MACHINE DESIGN, February, 1942). If there has been any stifling of war goods, the Government has had the full power and authority to correct the situation by proceeding under the act, leaving the inventor or the patent owner with his remedy to sue the Government for "reasonable" compensation in a court of claims.

The purpose behind the act as amended in 1918 is sound. From a practical point of view, however, the actual operation of the law greatly favors the Government and thus it does not appear, so far as the Government is concerned, that there is a great need for giving powers to the President to acquire patents. Experience shows, however, that the remedy to recover reasonable compensation in the Court of Claims is inadequate for the inventor. Procedure in the court is terribly slow. Thus the case involving the aircraft control mechanism on the plane in *Fig.* 4 took more than eleven years to decide. Besides being slow, the procedure is so costly to inventors that many valid claims are not even instituted. Under the present rules the patentee must file thirty-five printed copies of his petition. Other papers are also required to be printed at a big expense to the inventor. In addition, many technicalities and defenses are interposed by the Government. The inventor of the detonator for high-explosive shells, shown in *Fig.* 5, was denied his claim for compensation because of a valid defense by the Government.

Pending Bill Protects Inventors

One hopeful sign in the direction of removing all of these handicaps, so far as the inventor is concerned, may be derived from bill H.R. 7439 introduced on July 24, 1942, to regulate in the United States Court of Claims and in the United States district courts suits for payment for the infringement of patents and for the use of inventions used for or by the Government, to give better protection to the rights of inventors and owners of patents, and to stimulate invention.

This bill attempts to correct the defects which now exist, the following being worthy of note:

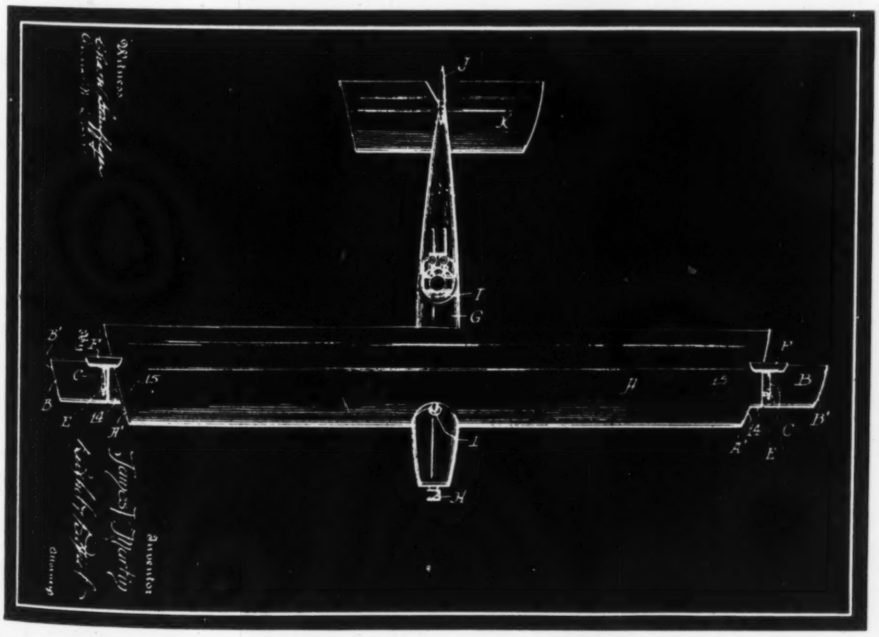


Fig. 4 — Aircraft control mechanism formed basis of claim which took eleven years to settle

1. It is not unpatriotic for an inventor or his assignee to sue the Government for the use of his invention, and no representative or employe in any department shall practice any fraud in favor of the Government in defending such suits
2. The Government shall admit material facts which the records and the equipment of the departments and their agents or contractors show to be true
3. The Court of Claims may order the legal representatives of the departments to assist the inventor in getting material evidence from the records of the departments and its agents and from its contractors, consistent with the public safety, or so long as it can be done without impairing the public safety

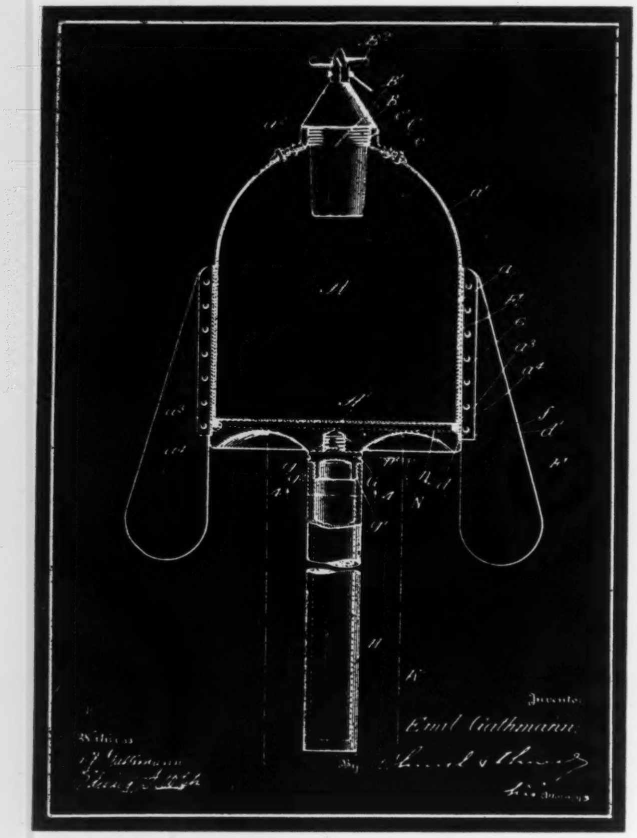
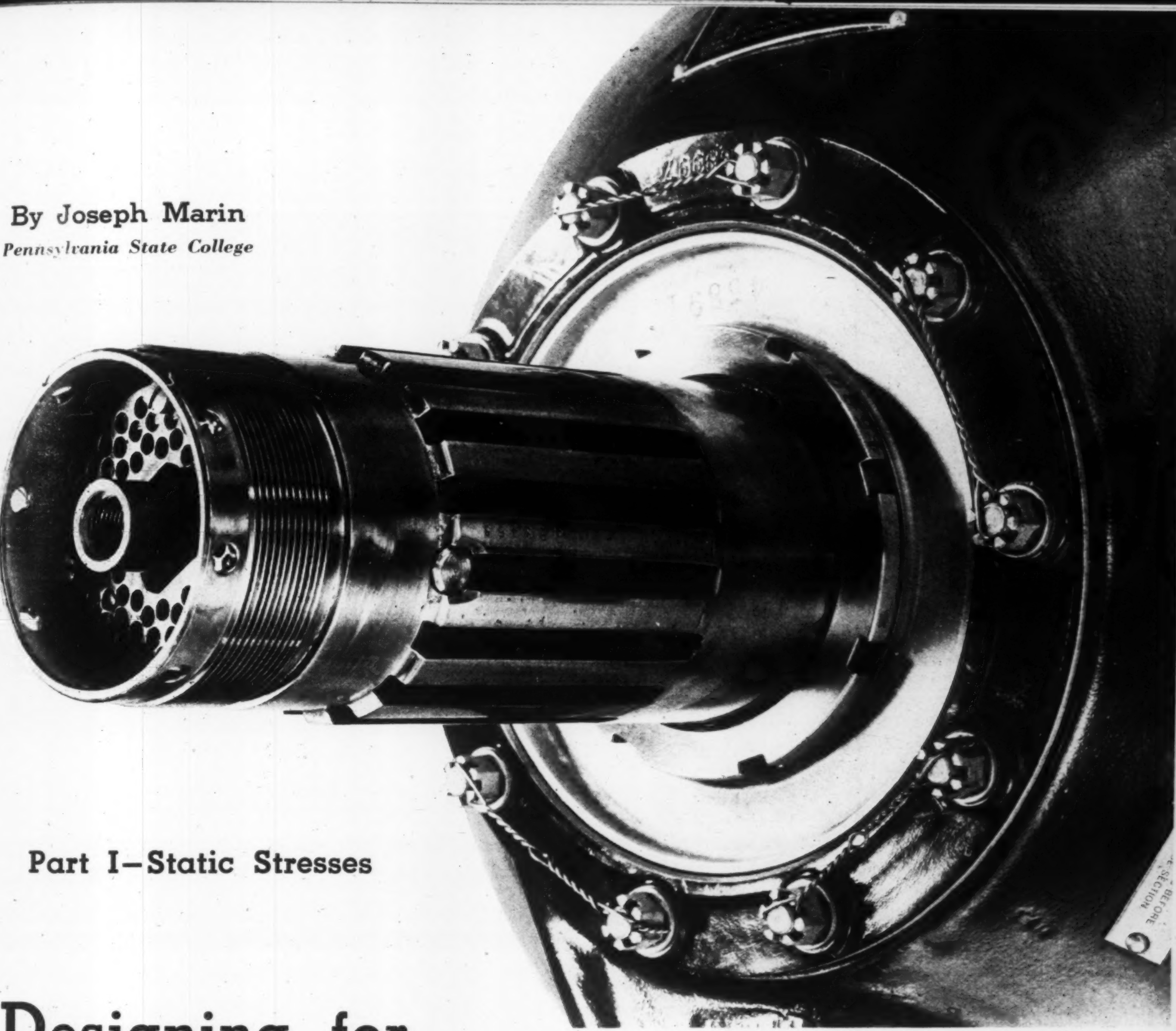


Fig. 5—Shell detonator design for which the inventor was denied compensation

4. If an invention is used by any department of the Government or its contractor, it shall keep records of such use from the time such use begins, and shall ascertain the name and address of the patent owner or inventor thereof, and in the event that a representative of any of the departments of the Government other than the Patent Office inspect an application, a record of such inspection shall appear in the application file
5. No contents of any application are to be divulged except as it may become necessary in the prosecution of the war and any information so obtained shall not be used by anyone adversely to the interest of the inventor
6. The defense of shop right is waived unless it is clearly proved that the inventor, after being fully informed of his rights, gave his consent to the use of his invention without pay, which consent must have been given without duress and at a time when the inventor had a legal or equitable right to prevent the use of his invention
7. The bill provides that the procedure is to be streamlined to avoid delays and is based upon the practice of the Federal courts
8. When a decree is given for the inventor or assignee of a patent and an accounting is ordered by the Court of Claims, the Department of Justice shall furnish the court reporter for the reporting of all depositions taken thereafter, and the Department of Justice shall pay the cost thereof and shall promptly furnish to the claimant without cost a copy of all depositions taken by both sides
9. If the inventor needs a Government expert witness, arrangements are to be made for this purpose
10. If the invention has been placed under secrecy orders, in accordance with law, the invention shall be deemed to be presumptively novel and useful
11. The use of the invention by a contractor on Government work for the benefit of the Government shall be considered to be a use by the Government
12. If the value of the invention, or the value of the use thereof, cannot be ascertained with reasonable certainty, the court may enter judgment on the basis of a reasonable royalty, for which purpose it may receive opinion or expert testimony to determine the full value of the use of the invention to the Government
13. In case material evidence is withheld by the Government because of failure to keep records of the use of invention, all doubts shall be resolved against the Government
14. No case shall be dismissed for lack of prosecution if any Government department or agency has refused to answer a call or has refused to answer interrogatories or has withheld material evidence or if material evidence has been withheld by another or others under Government direction.
15. The inventor shall be allowed full pay for the use of his invention, and no discount therefrom shall be made because the inventor is not a manufacturer
16. Interest at six per cent per annum shall be allowed on all judgments rendered in such suits from the time the use of the invention ended, or from the end of each calendar year of use until paid as the court may decree
17. If the payment of the claim is delayed, the income tax attributable to the income of the inventor shall not be greater than the aggregate of the taxes attributable to such income or compensation had it been received in equal portions without delay
18. If the invention has been disclosed to any officer or agent of the Government, the inventor shall have the right, upon receiving the patent therefor, to sue the Government for the use of the invention by or for the Government begun after such disclosure and before the patent was issued
19. The district courts of the United States shall have the same original jurisdiction of all suits that has heretofore been vested in the United States Court of Claims. In such suits the District Court has power to render judgments against the United States in favor of the inventor for his reasonable and entire compensation arising out of infringement or use.

Behind this new legislation is the realization that our very existence depends on maintaining the superiority over the Axis powers that American ingenuity can supply through new inventions and designs. More equitable treatment of the inventor cannot help but stimulate design, as exemplified by the mighty engine of destruction shown in *Fig.* 1, thus hastening the day when development work may once more be applied to the problems of a peacetime world.

By Joseph Marin
Pennsylvania State College



—*Photo, courtesy Curtiss-Wright Corp.*

Part I—Static Stresses

Designing for Bending, Twisting and Axial Loads

NUMEROUS machine members are subjected to a combination of bending and twisting moments and axial loading. Often these members are of circular cross section such as in shafting, an example being given in *Fig.* 1. There are, however, important applications where a member is of noncircular cross section and is subject to these combined loadings. Some instances are parts of crankshafts, helical springs and airplane members. In this discussion the design of these elements will be based on failure of a material by yield. The influence of buckling as a possible type of failure will be excluded. This possibility of failure, however, should not be overlooked, particularly in the design of thin-walled members. Machine elements subject to both static and fluctuating loads will be covered, with the present article confined to static loads. The in-

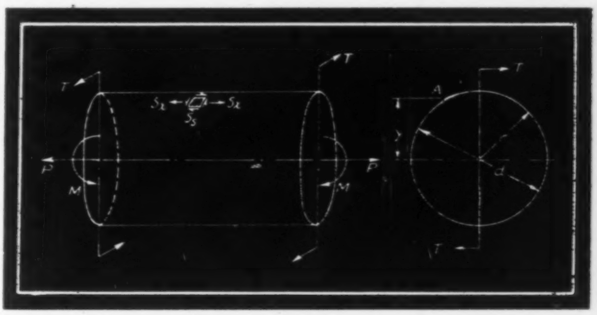


Fig. 1—Top—Aircraft propeller shaft is subject to combined stresses

Fig. 2—Above—Member of circular cross section with combined stresses

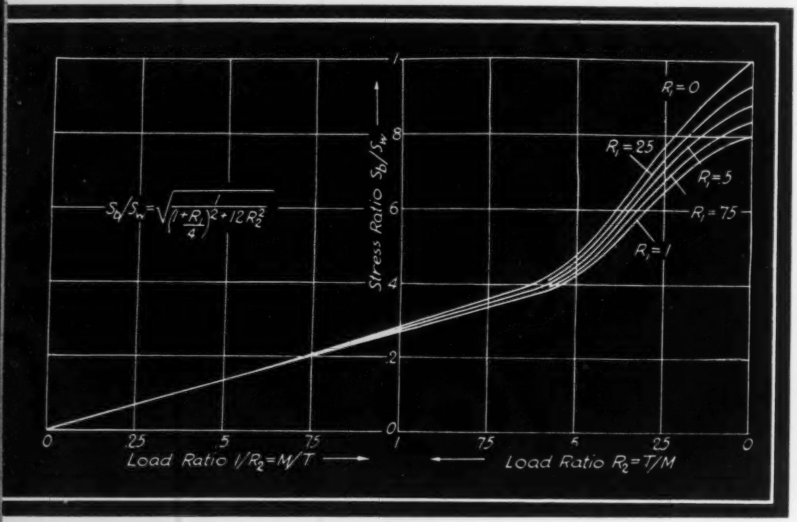


Fig. 3—Allowable stress ratios for various load combinations on circular cross-section member

fluence of a combined state of stress on the behavior of the material used will be considered in determining the required dimensions.

Before considering the combined stress effect it will be necessary to determine the stresses acting throughout the cross section of the member. After the loads have been determined it is usually possible to select the critical cross section for which the stresses are maximum. Usually the forces for this cross section can be resolved into a twisting moment, a bending moment, transverse shear and axial loading. Except for members in which the cross-sectional dimensions are large compared to their lengths and other special types of constructions, the transverse shear can be neglected in designing most members subject to combined loadings.

In determining the bending and twisting moments for nonsymmetrical cross sections it sometimes will be necessary to determine first the shear center—that point through which the load must be applied so that there is no twisting of the cross section. This will be necessary for members subject to bending which are not loaded in the plane of symmetry of the cross section[1]. For these and other members it is then possible to determine the bending moments, twisting moment and axial load for the critical cross section. For members with a cross section with at least one plane of symmetry and loaded in this plane of symmetry, the determination of these loads is simplified. The remaining discussion will be confined to members with cross sections having at least one axis of symmetry.

Stresses due to the bending moments can usually be calculated with sufficient accuracy by using the ordinary beam formula $S=My/I$. There are a number of conditions, however, where this formula does not apply, namely:

1. Beams of thin-walled construction in which failure by buckling might occur
2. Beams of relatively great depth. Deflections due to shear must then be considered
3. Beams with great width
4. Beams with wide flanges and thin webs
5. Curved beams.

Determination of the stresses due to twisting moments offers greater difficulty than the calculation of bending stresses. This is because the torsional stresses in only a few members have been determined theoretically. That is, the equation for the shear stress for the circular cross section, $S_s=Tr/J$, does not apply to other shaped cross sections. Theories are available for torsional stresses in a few cross sections as, for example, rectangular and elliptical sections. For other members an experimental procedure using the membrane analogy has been found useful[2].

The determination of stresses due to axial loading does not offer difficulty if the load passes through the centroidal axis and if the member is straight. If the load is compressive the relative values of the cross-sectional dimensions to the length must be considered due to possible failure by buckling.

In the following examples specific members subject to bending, twisting and axial loadings are designed, considering the combined stresses and their effects on the behavior of the material. Other design considerations such as allowable deformations, including deflections and angles of twist, will not be discussed.

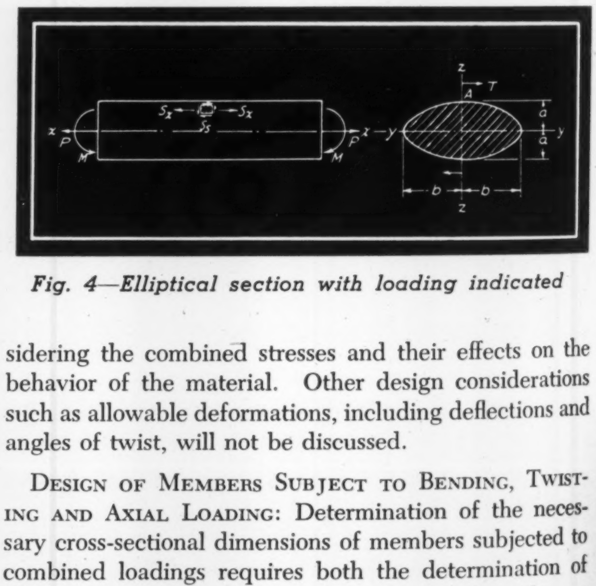


Fig. 4—Elliptical section with loading indicated

DESIGN OF MEMBERS SUBJECT TO BENDING, TWISTING AND AXIAL LOADING: Determination of the necessary cross-sectional dimensions of members subjected to combined loadings requires both the determination of the combined stresses and a provision for the influence of such stresses on the resistance of the material used. This latter influence will be considered by using the distortion-energy theory. For the members discussed the stress components consist of a normal stress S_x produced by bending the axial loads and a shear stress component S_s produced by the twisting moment. Then the working stress in terms of these stress components is S_w where

$$S_w^2=S_x^2+3S_s^2 \quad \text{(1)}$$

Using Equation 1 for the critical element in a member and replacing the values of the stress components in terms of the loads and dimension, the unknown dimension of the cross section can be calculated. This procedure will be outlined and values given for several types of members.

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[1] For a discussion of shear center see W.L.S. Schwalbe—"The Center of Torsion for Angle and Channel Sections", *Transactions*, A.S.M.E., Vol. 54, Page 125, 1932, and R. J. Roark—*Formulas for Stress and Strain*, McGraw-Hill Book Co., 1938.

[2] For a development of both the theoretical and experimental procedures and for equations giving torsional stress values see S. Timoshenko—*Theory of Elasticity*, McGraw-Hill Book Co., 1934; and G. W. Trayer and A. W. March—"The Torsion of Members Having Sections Common in Aircraft Construction", N.A.C.A. *Report* No. 334.

Example 1—Member of Circular Cross Section: For a member of circular cross section as shown in *Fig.* 2, the stresses for an element at A produced by a bending moment M, an axial load P and a twisting moment T are, respectively,

$$S_b=\frac{My}{I}\,,\qquad S_a=\frac{P}{A_r}\,,\qquad S_s=\frac{Tr}{J}\quad\ldots\ldots\ldots\ldots(a)$$

where I is the moment of inertia of the cross section; A_r, the area of the cross section; and J, the polar moment of inertia of the cross section.

For this cross section the stress values are all maximum at the outer fiber. The stress components then are

$$\left.\begin{aligned} S_x=S_a+S_b=\frac{P}{A_r}+\frac{Mr}{I}=\left(\frac{1}{\pi r^2}\right)\left(\frac{4M}{r}+P\right)\\ S_s=\frac{Tr}{J}=\frac{2T}{\pi r^3}\quad\ldots\ldots\ldots \end{aligned}\right\}\ldots(b)$$

Placing the values of the stress components from Equations b in Equation 1, the working stress S_w is defined by

$$S_w^2=\left(\frac{1}{\pi r^2}\right)^2\left(\frac{4M}{r}+P\right)^2+3\left(\frac{2T}{\pi r^3}\right)^2\quad\ldots\ldots\ldots\ldots(c)$$

Variation in the required radius r can be represented by rewriting Equation c as follows:

$$\frac{S_b}{S_w}=\sqrt{\frac{1}{\left(1+\frac{R_1}{4}\right)^2+12R^2}}\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where R_1 *is* Pr/M and R_2, T/M.

The allowable stress ratio, S_b/S_w, representing the ratio of the bending stress to the working stress, is given by Equation 2. The variation in this value is shown in Fig. 3 for various load combinations as indicated by the variation in values of load ratios R_1 and R_2. Since the stress ratio $S_b/S_w=4M/\pi r^3 s_w$, the value of the radius r can be selected when the ratio S_b/S_w is known. In using *Fig.* 3 for calculating the radius a trial and error procedure must be used since the selection of R_1 depends upon an assumed value of the radius r. Only a few trials, however, will be necessary before the correct value of r is selected.

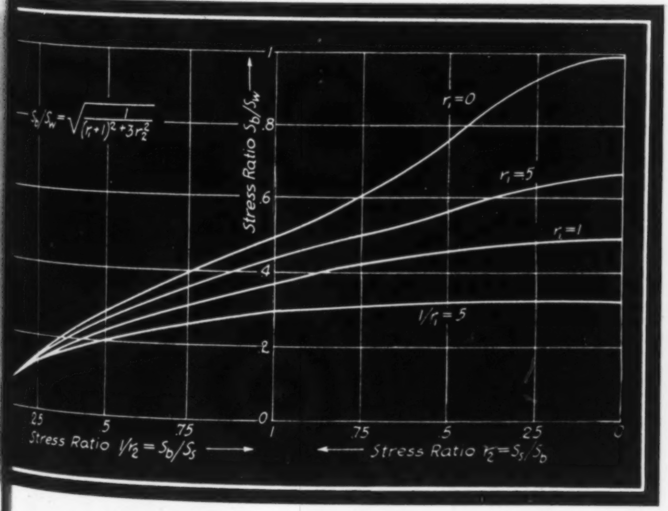


Fig. 5—Stress ratios for loading of elliptical sections

Stresses in Elliptical Members

Example 2—Member of Elliptical Cross Section: For an elliptical section as shown in *Fig.* 4, with a bending moment M acting about the major axis $y—y$, the maximum stresses occur at the outer fiber at A. The stress values at this element are

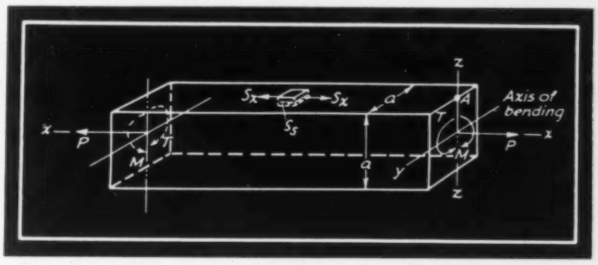


Fig. 6—Element in member of square cross section

$$S_b=\frac{Ma}{I_y}\,,\qquad S_a=\frac{P}{A_r}\,,\qquad\text{and } S_s=\frac{Ta}{2I_y}\quad\ldots\ldots(d)$$

where $2a$ is the length of the minor axis and I_y is the moment of inertia about the major axis $y—y$. Placing the values of the stress components from Equations d in Equation 1,

$$S_w^2=\left(\frac{Ma}{I_y}+\frac{P}{A_r}\right)^2+3\left(\frac{Ta}{2I_y}\right)^2\quad\ldots\ldots\ldots\ldots\ldots\ldots(e)$$

or

$$\frac{S_b}{S_w}=\sqrt{\frac{1}{(1+r_1)^2+3r_2^2}}\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where r_1 is the stress ratio S_a/S_b and r_2 the stress ratio S_s/S_b.

Equation 3 gives the allowable value of the bending stress ratio S_b/S_w. A plot of this equation for different stress ratios r_1 and r_2 is given in *Fig.* 5. This design diagram can be used in a manner similar to *Fig.* 3 for the circular section. If b is known and it is necessary to find a, the method used must be a trial and error procedure. Assuming a value of a, the stress S_a, S_b and S_s can be determined from Equations d and hence the stress ratios r_1 and r_2 can be calculated. Using *Fig.* 5, the allowable value of the stress ratio S_b/S_w is selected and hence the required value of a calculated. If the assumed value is different from this calculated value the procedure is repeated with a new value of a until the initial and final values agree.

If bending exists about the minor axis $z—z$, the critical element cannot be selected by inspection and the element for which the distortion energy is a maximum must be obtained by calculus. For an element with coordinates z and y the stress values are

$$\left.\begin{aligned} S_b=\frac{My}{I_z}, \quad S_a=\frac{P}{A_r} \\ S_s=\frac{T}{2}\sqrt{\frac{y^2}{I_z^2}+\frac{z^2}{I_y^2}} \end{aligned}\right\} \quad \ldots\ldots (f)$$

Value of the distortion energy for an element in this member in terms of the stress components is

$$V=k(S_x^2+3S^2_s) \quad \ldots\ldots (g)$$

The critical element for which the distortion energy is a maximum can be selected by first placing the stress values from Equations f in Equation g. Determination of the derivative dV/dx can be made and the critical element selected by placing this derivative equal to zero.

EXAMPLE 3—MEMBER OF SQUARE CROSS SECTION: For a member of square cross section with bending about an axis of symmetry combined with torsion and axial loading, the critical element is at A where all stresses are maximum, *Fig*. 6. The values of the stress components are

$$S_b=\frac{6M}{a^3}, \quad S_a=\frac{P}{a^2} \quad \text{and } S_s=\frac{T}{.208a^3} \quad \ldots\ldots (h)$$

Placing the values of the stresses from Equations h in Equation 1, the allowable bending stress ratio is

$$\frac{S_b}{S_w}=\sqrt{\frac{1}{(1+6R_1)^2+1.90R_2^2}} \quad \ldots\ldots (4)$$

where, R_1 is $Pa/36M$ and R_2, T/M.

Variation in the bending stress ratio is shown in *Fig*. 7 for various possible values of the load ratios R_1 and R_2. This diagram can also be used for selecting the required value of the dimension a by assuming a value of a in order to determine R_1 and R_2, and then proceeding as explained in the foregoing examples to determine the correct value of a.

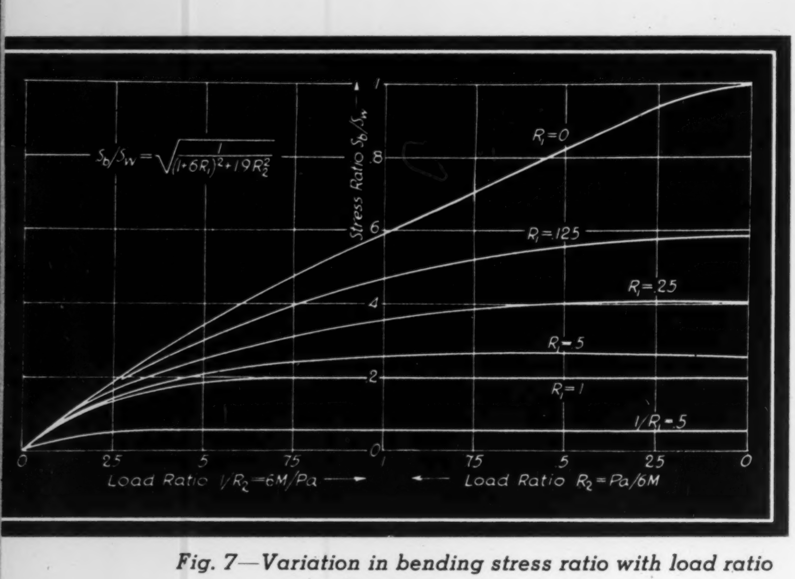


Fig. 7—Variation in bending stress ratio with load ratio for square cross section

For a square section subject to bending and torsion only, the value of a can be determined directly by Equation 4 since R_1 is 0 and

$$\frac{S_b}{S_w}=\sqrt{\frac{1}{1+1.90R_2^2}}$$

or

$$a=\sqrt[3]{\frac{6M}{S_w}\left[1+1.90\left(\frac{T}{M}\right)^2\right]^{1/2}} \quad \ldots\ldots (4a)$$

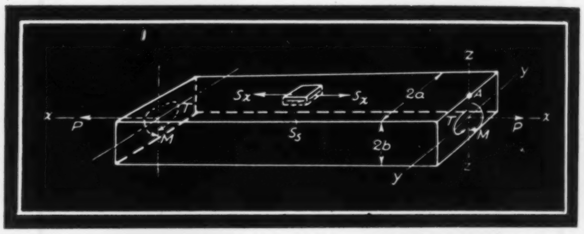
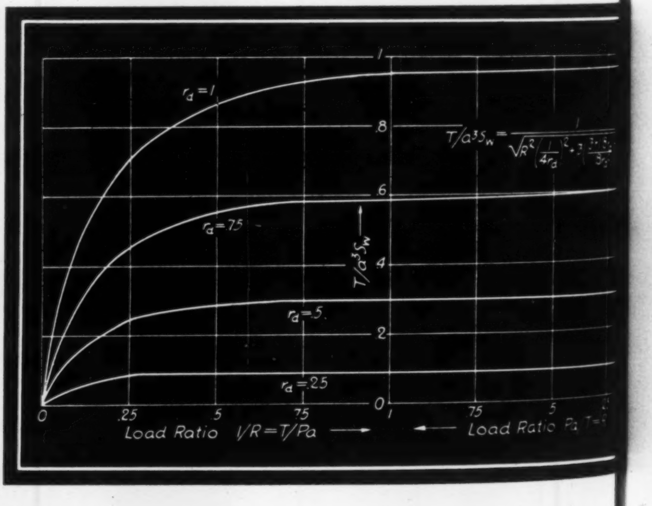


Fig. 8—Rectangular section with loadings indicated

Fig. 9—Allowable values of width of rectangular section for various load ratios



This equation gives directly the required dimension a for a selected working stress S_w and known moments M and T.

EXAMPLE 4—MEMBER OF RECTANGULAR CROSS SECTION: For a member of rectangular section as shown in *Fig*. 8, of cross section $2b$ by $2a$ where a is greater than b and bending occurs about the axis $y—y$, the maximum stresses are at point A and their values are

$$S_b=\frac{Mb}{I_y}, \quad S_a=\frac{P}{A_r}, \quad S_s=\frac{T(3a+1.8b)}{8a^2b^2} \quad \ldots (i)$$

Value of the shear stress determined by Equation *i* is an approximate one. The error in this stress value, however, does not exceed 4 per cent.

Placing the values of the stress components from Equations *i* in Equation 1, the allowable value of *a* for a given value of *b* can be calculated. The equation for doing this is

$$S_w^2=\left(\frac{P}{4ab}+\frac{3M}{4b^3}\right)^2+3\left(\frac{T(3a+1.8b)}{8a^2b^2}\right)^2 \quad\ldots\ldots(5)$$

For a rectangular section subject to torsion and axial loading, the required value of *a* becomes, by Equation 5,

$$a=\sqrt[6]{\left(\frac{T}{S_w}\right)^2\left[R^2\left(\frac{1}{4r_d}\right)^2+3\left(\frac{3+1.8r_d}{8r_d^2}\right)^2\right]} \quad\ldots(5a)$$

where R is Pa/T and r_d, b/a. Variation in the value of a for different values of the load ratio R and ratios r_d of the dimensions are represented in *Fig.* 9 by plotting T/a^3S_w versus the load ratio R for various values of r_d. *Fig.* 9 or Equation 5*a* can be used for selecting the required value of *a*.

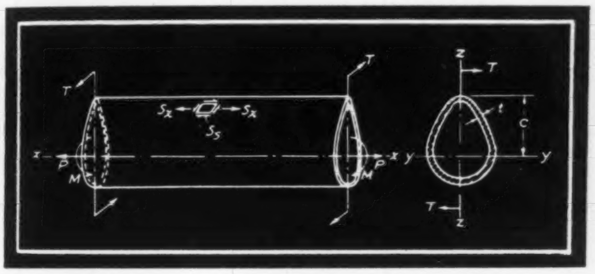


Fig. 10—Loading on thin-walled section with one axis of symmetry

If bending takes place about the axis z—z in place of y—y it becomes necessary to select the critical element by determining the value of z for the maximum value of the distortion energy. This leads to mathematical complications due to the complicated value for the shearing stress.

Determining Wall Thickness

EXAMPLE 5—MEMBER OF HOLLOW THIN-WALLED CROSS SECTION: For a member of hollow thin-walled cross section, as shown in *Fig.* 10, the shearing stress due to the twisting moment T can be assumed uniform if the wall thickness is small and constant compared to the other dimensions. It can then be shown that the shear stress is approximately

$$S_s=\frac{T}{2tA_m} \quad\ldots\ldots(j)$$

where A_m is the mean of the areas enclosed by the outer and inner boundaries of the cross section.

If the cross section has at least one plane of symmetry with the bending loads acting in this plane, then the bending stress is

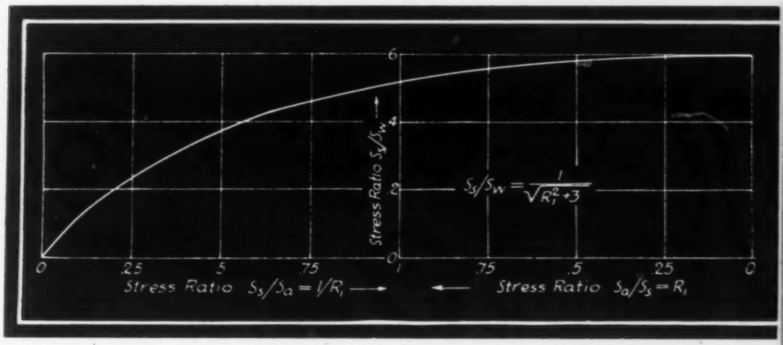


Fig. 11—Shear-stress ratio plotted against load ratio for thin-walled section in Fig. 10

$$S_b=\frac{Mc}{I} \quad\ldots\ldots(k)$$

Stress due to the axial load P is

$$S_a=\frac{P}{A_r} \quad\ldots\ldots(l)$$

where A_r is the cross-sectional area of the wall.

Placing the values of the stress components from Equations *j*, *k* and *l* in Equation 1, the required wall thickness t is determined by the resulting equation, namely,

$$S_w^2=\left(\frac{Mc}{I}+\frac{P}{A_r}\right)^2+3\left(\frac{T}{2tA_m}\right)^2 \quad\ldots\ldots(6)$$

For a thin-walled section with torsion and axial loading only, Equation 6 can be written

$$S_w^2=\left(\frac{P}{A_r}\right)^2+3\left(\frac{T}{2tA_m}\right)^2$$

or

$$\frac{S_s}{S_w}=\frac{1}{\sqrt{R_1^2+3}} \quad\ldots\ldots(6a)$$

where

$$R_1=\frac{S_a}{S_s}=\frac{2PtA_m}{A_rT}$$

The variation in the shear-stress ratio (S_s/S_w) with variation in the load ratio R_1 as given by Equation 6*a* is plotted in *Fig.* 11. The required wall thickness can be determined by this diagram using a trial and error procedure as previously explained.

The foregoing examples serve to illustrate the procedure and give design graphs for members of various cross section subject to bending, torsion and axial loading. In using these results the designer must also consider the possibility of failure by buckling or the possibility of excessive deformations such as large angles of twist or deflections.

Practical Aspects of Bearing Design

Part I—Lubrication

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Research Laboratories Division
General Motors Corporation

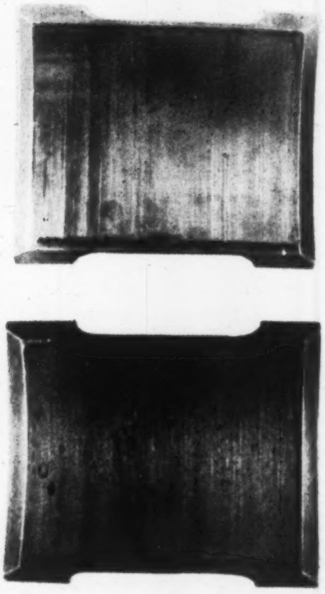

Fig. 1—These two 60-degree partial bearings have run three times as long as the 180-degree bearing in Fig. 2

IN LAYING out a new piece of apparatus, especially along mechanical engineering lines, the bearings are often one of the main points around which the design evolves. In general, handbook data are not useful in bearing design. These data mostly deal with results of tests on coefficient of friction between sliding surfaces, or specific determinations on a bearing. There is little doubt but that the data are correct for the specific conditions under which the test was run. However, data covering the operating conditions often are not complete or are not applicable to the problem under consideration. Bearing applications in all but "copy" engineering are so varied that basic principles are necessary.

For about ten years, our laboratories have had the project of investigating the problems connected with journals and their supports. Perhaps the greater portion of the effort has been to learn more about how and why bearings run than to determine the coefficient of friction and temperature rise. In this paper it is desired to set down the principles which our experience shows are necessary to understand why properly operating bearings do run, and how to design a bearing while on the drafting board.

Satisfactory bearing designs usually may be worked out mathematically. A number of investigators have made and published rather complete information.[*] However, unless the designer has had some background of practical experience, or a suitable testing device is at hand, it is difficult to ascertain whether the design is the best that can be had considering the physical dimensions upon which the design is based. Furthermore mathematical analysis is only one of the many points of bearing design and should not consume too much of the designer's energy juggling complicated formulas.

PRESENTING practical design information on plain bearings, so vital under present conditions, this article is based on a recent S.P.E.E. paper. The second part, to be published next month, will cover materials

In outline, the important things in regard to plain bearings that a designer should know are as follows:

A. The capacity, considering the physical dimensions and operating data
  1. Kind of bearing metal
    (a) Ratio of maximum oil film pressure to unit pressure of projected area
    (b) Bearing metal thickness
  2. Static or alternating loads
  3. Oil
    (a) Grade
    (b) Stability
    (c) Pressure
    (d) Grooves for cooling purposes
    (e) Temperature rise

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[*] See references at end of article.

Table I
Allowable Pressure on Bearing Alloys

Alloy	Composition % Lead	Tin	Antimony	Copper	Cadmium	Nickel	Silver	Approx. max. load capacity,** lb. per sq. in. of proj. area
Lead base No. 1	95-97							200-300
Lead base No. 2	75-85	4-10	9-15					600-800
Tin base	.35-.6	86-90	4-9	4-6				800-1000
Cadmium base				.4-.75	97	1-1.5	.5-1.0	1200-1500
Copper-lead No. 1	45			55				2000-3000
Copper-lead No. 2	25	3		72				3000-4000
Silver	.5-1*						99	5000-up

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*Lead on surface for running-in purposes.

**Based on fatigue life of 500 hours at 300 degrees Fahr. bearing temperature, and a bearing metal thickness .01 to .015-inch for lead, tin and cadmium base metals, and .025-inch for the copper-lead and silver. At lower temperatures the life will be greatly extended. Capacities shown may also be expected to resist maximum film pressures up to 2½ times the unit loading.

B. Safety Factor
  1. Minimum oil film thickness

C. Power Loss
  1. Low friction coefficient in consideration of driving power requirements
  2. Friction power per unit of surface
  3. Partial bearings.

Assuming fluid lubrication, a designer's first consideration in attacking any bearing problem is whether the dimensions set up will support the load. For a new and untried design, or for an inexperienced designer, the safest treatment is to work the problem out. Howarth's (1)* data on partial bearings; Needs' (2) for 120-degree and 360-degree bearings, or Dennison's (3) for 360-degree bearings, have been found to give good agreement with practice. Except for the Dennison data, no account is taken of the fact that the bearing may operate under alternating load. For some reason which is not yet clear, experimental facts show that a plain journal bearing under an alternating load will support two or three times the calculated capacity, while other factors, such as power loss, remain essentially the same as calculated. This fact may be used as a design safety factor, or if the bearing is limited by the physical dimensions, the ultimate capacity (two to three times the calculated) may be used with proper choice of bearing material to extend the fatigue life.

Table I has been arranged to give the designer complete control over the choice of bearing materials for the extension of fatigue life. The table may be also used for selection of bearing metals under static loads. However, bearings designed for static loads must of necessity carry low unit pressure, otherwise they will be difficult to start. Depending on the temperature at the time, the torque required to start plain bearings under load may be as much as ten or twenty times as much as the running torque. General practice indicates that the unit loading should be on the order of 250-300 pounds per square inch for starting purposes under load, unless some external means is applied to release the metal to metal contact. This may be done by feeding high pressure oil into the bearing on the loaded side to lift the journal temporarily until in motion.

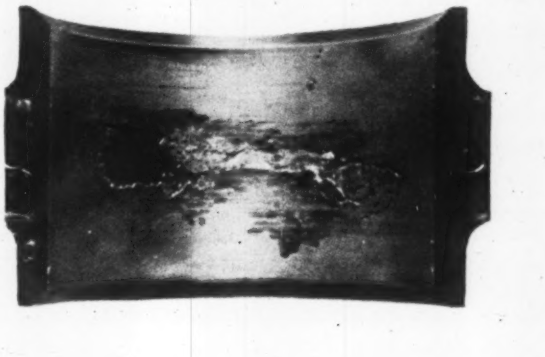


Fig. 2—Condition of 180-degree bearing indicates lower capacity than 60-degree partial bearings in Fig. 1

Local Pressures Exceed Average

A point which is often overlooked as regards plain bearing loads is the ratio of maximum film pressure to the unit load of projected area. The ratio normally runs about two or three. However, for bearings with large clearances, or small values of L/D the ratio may be as much as five or six. This is important when bearing materials of low yield point are used. When the metal yields, due to exceeding the elastic limit, the load (revolving) increases the clearance, and the oil film arc becomes less in extent. The unit loading (P_o) is increased thereby, as well as the ratio $P_{max.}/P_o$ due to the increased eccentricity. A vicious cycle is generated, so to speak, whereby conditions become worse and worse. Under static loads, when the metal yields the *effective* clearance is reduced, increasing the power loss and decreasing the safety factor of the bearing through the reduction of minimum film thickness. This yielding effect of low strength materials may be alleviated to a considerable degree by the use of a thinner layer. On alternating loads the fatigue life is also improved by this method. A limit is reached, however, when the layer becomes so thin that the metal will no longer conform to the journals when the shaft or the connecting structure deflect due to bending. This factor is especially apparent when the L/D ratio is greater than one. Unless suitable testing devices are available, it is probably best not to go below .025-inch in thickness of bearing metal for most designs.

In nearly all of our studies of reference work on plain bearing design, the only requirement that is placed on the oil is that the absolute viscosity in the bearing be as calculated, or nearly so. This is obviously the most important requirement. However, there are other requirements which should be met for the oil, and which can be more or less responsible for the success of the bearing. For instance, the viscosity index should be reasonably high (50-100). This provides for lower torque on cold starts, and more capacity if the bearing temperature should run higher than estimated. Stability of the oil is important if the journal is to be run at high speeds with a bearing temperature of 250 degrees Fahr. or over. At this temperature some oils readily oxidize and coat the bearing with a layer of varnish. The clearance is thus reduced and the flow of oil through the bearing for cooling purposes is reduced also. There is thus a temperature build-up which, if allowed to continue long enough will ultimately end in bearing failure by seizure. Oxidation also produces organic acids which will attack and corrode away some bearing alloys. This produces the opposite effect of that just mentioned. As the metal is lost by corrosion the clearance is increased and the oil film arc becomes less in extent. The unit pressure is increased and a circumstance is presented similar to the low yield situation just discussed.

Oil pressure is rarely mentioned in reference work on bearing design. The assumption is that the clearance space is always full of oil. Experiments have shown, however, that excessive oil inlet pressure increases the power loss in plain bearings. Excessive pressure not only cools the bearing more thoroughly (with subsequent rise in viscosity and power loss) but increases oil flow out of the bearing, which increases losses due to end effects. This is especially true of bearings in the larger diameter sizes. Oil pressure also increases the bearing load if only one inlet hole or a half groove is used on the unloaded side of a full journal bearing. Only when bearings have a L/D ratio greater than one does this have an appreciable effect.

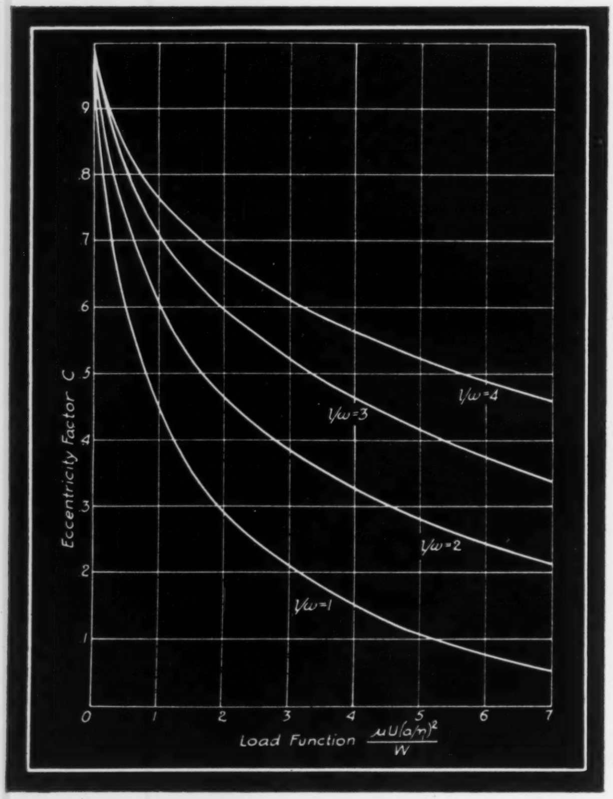


Fig. 3—Chart determines eccentricity of a loaded 120-degree partial bearing

The best way to lubricate a bearing is by a circumferential groove. From a cooling standpoint, this is also the most effective method. The weakness of the design is that the effective L/D ratio is cut to one half, compared to the same bearing without a groove. This reduction is equivalent to a decrease in capacity of 30 to 50 per cent, depending on the bearing size. Oil holes cause a forced flow across the bearing face very similar to that of a groove, and if located out of the loaded area there is no reduction in capacity. However, the *oil flow capacity* is reduced and hence the cooling is reduced also. Axial grooves are believed to serve no useful purpose that cannot be better served without them. The same is true of diagonal grooves and of recesses or pockets at the parting lines. They are ineffective for cooling because the oil takes the easiest path through the groove to the ends, rather than across the bearing face.

Temperature Is Basic Consideration

Temperature rise of the oil is important (oil into bearing minus oil out of bearing) because in pressure fed bearings, at least, most of the power loss is given up to the oil. A safe figure has been found to be about 50 degrees Fahr. A lower figure would be even safer. In this connection it would be well to note bearing temperatures, for this figure is a basic design requirement. This is true because the bearing oil film temperature is taken as that of the bearing surface. Our investigations have shown that average bearing temperatures range 50-75 degrees Fahr. higher than the oil inlet temperatures. In extreme cases 100 degrees Fahr. rise may be allowed, for high speed and high strength bearings.

Another important item for the designer is the minimum oil film thickness. Next to the consideration of the bearing's ability to support the load, this characteristic carries the most significance. Some investigators have called it a safety feature. For, if the minimum film thickness is too small it will not allow foreign matter to pass through the bearing. If the bearing material is one of the common babbits these will allow dirt particles to embed. But if the bearing is of a higher strength, with greater hardness, foreign matter in the oil will not embed so well and the metal-to-metal contact obtains. This action is usually accompanied by the evolution of considerable heat which the oil supply, now being cut off, cannot carry away. The net result is the characteristic seizure or "burning out". Larger minimum oil film thickness also indicates a greater load distribution which, as mentioned before, is desirable on the softer materials from the low yield standpoint.

Although we have calculated a number of bearings including successful, unsuccessful, and borderline types, we do not as yet feel free to quote with a great deal of confidence any limit on the minimum film. Bearing materials vary widely in their capacities and are being constantly improved. Our practice up to now on this function is to use a minimum limit for alternating or pulsating loads, $h_o/a=.0001=\eta/am$, and for static loads, $h_o/a=.00025=\eta/am$, where h_o=minimum film thickness, a=radius of journal, η=radial clearance, m=eccentricity modulus$=1/(1-c)=\eta/h_o$, and c= eccentricity factor=eccentricity/radial clearance.

If some idea of the power loss in bearings of a new machine were readily available, it would allow the designer more complete control over the total power requirements. There has been a tendency in some quarters to treat bearing power loss more or less vaguely and with some mystery. As a matter of fact, bearing power loss may be computed with comparative ease.

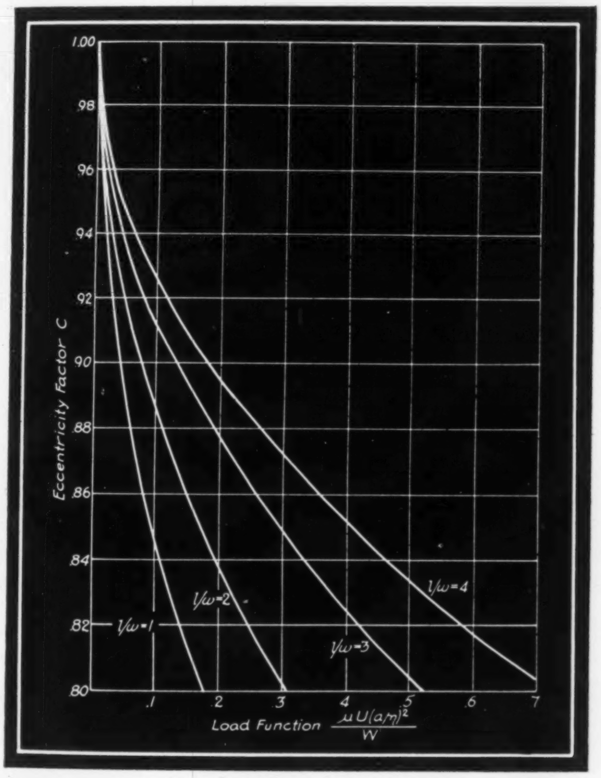


Fig. 4—Upper left-hand portion of Fig. 3 to an enlarged scale for accurate determinations

If the load, speed, and physical dimensions of a bearing are known, and viscosity of the oil film can be estimated, then the power loss can be determined with reasonable accuracy by the use of the data as supplied by Needs (2) for the value of $W/\mu U(a/\eta)^2$ and eccentricity ratio c for various l/w ratios. However, instead of plotting $W/\mu U\ (a/\eta)^2$ directly against c, it will be noted from *Figs.* 3 and 4 that its reciprocal has been used. This provides a more useful arrangement, for when $c=1$, $\mu U\ (a/\eta)^2/W=0$.

For a bearing with an arc of contact 120 degrees, the ratio of length in the direction of motion to bearing width is $l/w=\pi D/3w$ where D=bearing diameter, inches, and w=bearing width, inches.

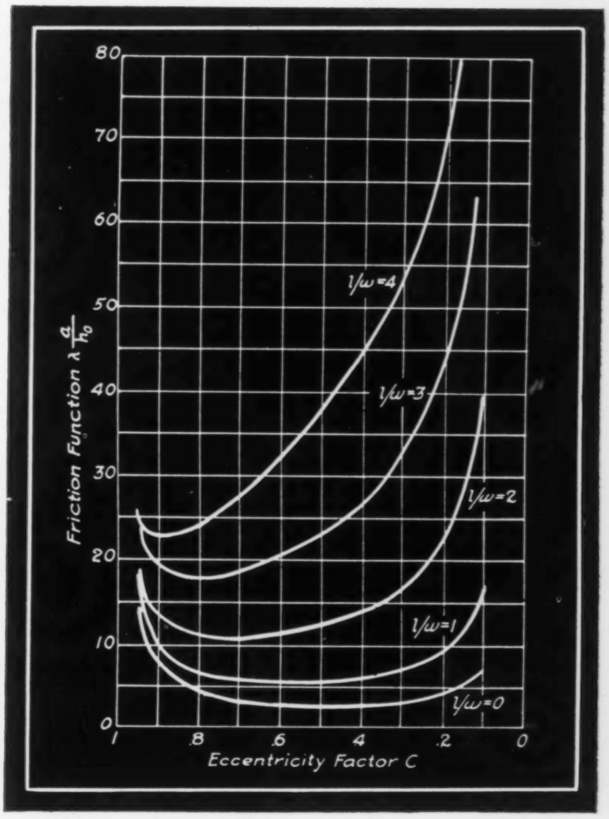


Fig. 5—Chart determines friction function for a loaded 120-degree partial bearing for accurate determinations

The load function is $\mu U(a/\eta)^2/W$, where W= $(load)/w$, pounds per inch width, μ=oil viscosity in the bearing, inch-pound-seconds, U=rubbing velocity$=2\pi aN/60$ inches per second, a=journal radius, inches, N=journal speed, rpm, and η radial clearance, inches.

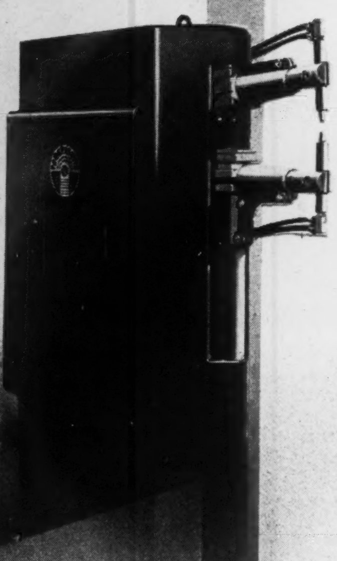
Assume η=.001-inch per inch of diameter unless known. For diameters under 5 inches and alternating loads, .00075-inch per inch diameter may be used for noise reduction. In general, depending upon the bearing material, larger clearances will give less power loss but the capacity for fluid lubrication will be reduced.

From the calculated values of l/w and $\mu U(a/\eta)^2/W$ the eccentricity factor c is found from *Fig.* 3 or *Fig.* 4. The minimum film thickness is $h_o=\eta(1-c)$, and should not be less than the limiting values previously noted.

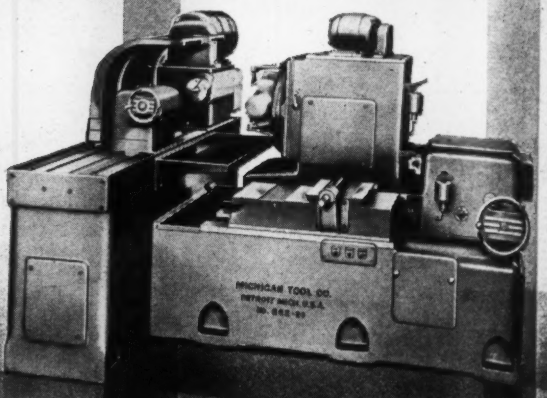
Knowing the values of c and the ratio l/w, the friction function $\lambda a/h_o$ can be found with the aid of *Fig.* 5. The coefficient of friction, λ, can therefore be calculated and friction drag$=\lambda\times$load. Then horsepower loss$=(U\times drag)/(12\times 550)$.

Using the computed value of friction drag, the power loss per square inch of bearing surface is $p_s=(U\times drag)/(2\pi aw)=(N\times drag)/(60\times w)$ inch-pounds per second per square inch. This function is useful for comparative purposes only, but may well be the

(*Concluded on Page* 148)



Left—Meeting a wide range of requirements, Progressive rocker-arm welders can be operated by foot, air or motor. Vertical adjustment is made by moving the lower arm, which also may be rotated in the holder so that welding can be performed with the electrodes at an angle



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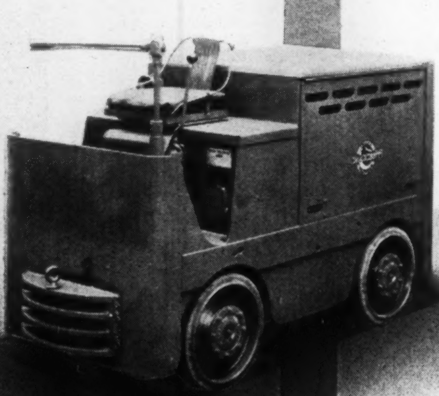
Right—With four-wheel knuckle steer and 48-inch wheelbase the Crescent tractor can negotiate a right-angle turn in a 65-inch aisle. Hauling a 30,000-pound trailer load, the tractor has a speed of 3 to 4 miles per hour. When operator leaves seat, brakes are automatically applied and circuit is broken at controller



Below—Multiple steam cylinders contribute to smooth operation of the Clark compressor. Vertical unaflow power cylinders and horizontal compressor cylinders coupled to a single crankshaft result in a compact unit

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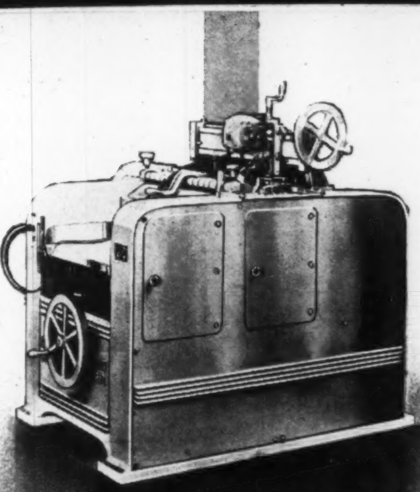
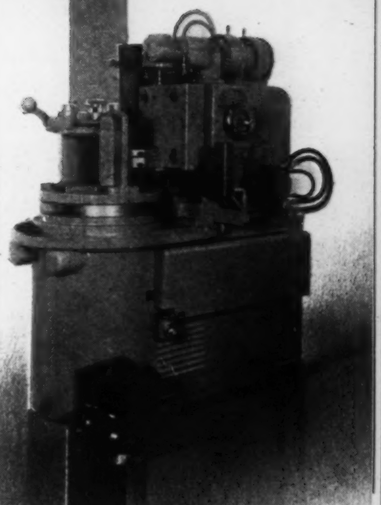


Left—Micrometer central control of the pressure bar insures accurate planing without twisting the stock in the Buss cabinet surfacer. Baffle plate extending the length of the cutter head deflects shavings, slivers and loose knots



Above—designed for cut extractor trunnion pockets in gun breech ring the Snyder special milling machine attains higher production rate than could be met b toolroom set-up methods. Oscillation of the table and the tool advance are hydraulically actuated, and no special attachments such as tracers or duplicators are required

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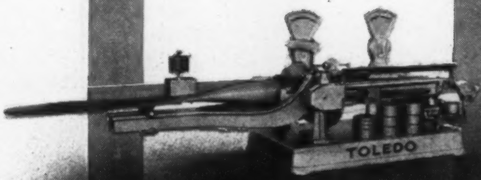

Left—Permitting blades to be made fully interchangeable due to uniformity of balance, the Toledo propeller balancing scales indicate both longitudinal and transverse condition of balance. Automatic pendulum counterbalance and oil dashpot insure high-speed operation

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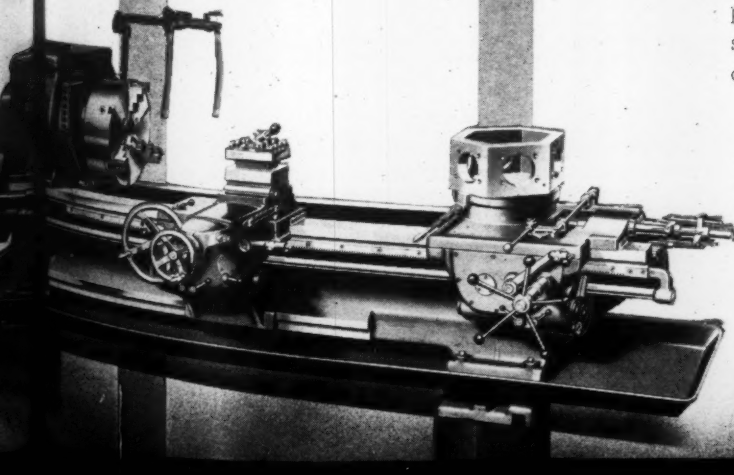
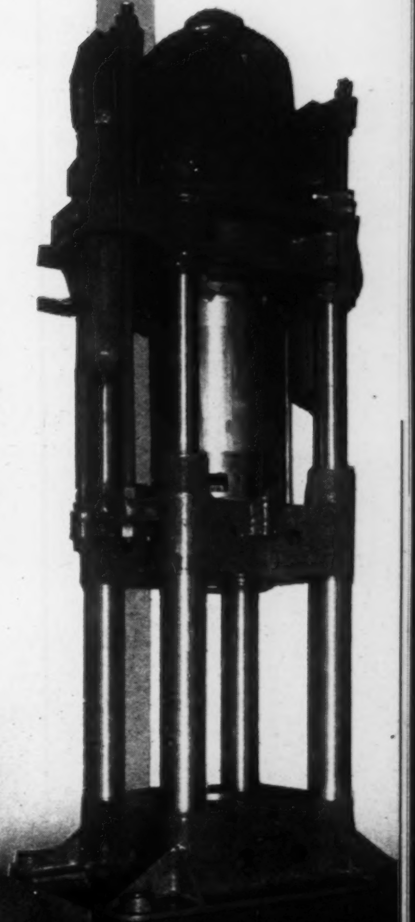


Right—Designed for shell production, the Baldwin 500-ton piercing press is of cast steel construction. Rams are cast iron, cylinder guides and column guides are bronze bushed. Distance between platens is 99 inches and the stroke is 42 inches. The press can deliver 240 strokes per hour, 24 hours per day



MACHINE DESIGN Editorial

Time for Design Changes Is Fast Approaching

STANDING out among Hitler's bad guesses is the one in which he underestimated American capacity for design and production. Giving him credit for having guessed correctly in certain instances, something must have gone wrong with his—and Hirohito's—thinking processes when they believed they could safely number among their opponents the developers of interchangeability, mass production, and the "machine age".

If their challenge was based on the early elimination of the remaining allied nations, on quick total victory, or on the unavailability to us of basic raw materials, they still were bad guessers. The last-named point—shortages of materials—cannot be viewed lightly, however. It is one that may well be the means of changing the strategic production policy of the United Nations.

Thus far, speed and quantity of production have been emphasized as vital requirements for victory. There is, though, a limit to the quantity of war equipment that can be produced, particularly if all the resourcefulness that can be displayed fails to develop satisfactory substitutes where shortages of materials occur. Under such a circumstance, quality rather than quantity becomes the paramount need.

Engineers responsible for design cannot fail to recognize this coming phase. Efforts to conserve, to substitute, and to design primarily for immediate speedy production necessarily will have to be subordinated, as production peaks become more nearly reached, to the designing of equipment that without any question is second to none in the air, on land and at sea.

Successful as has been this country's war equipment up to now, it is natural that "bugs" should show up on the field of battle. It would be asking too much to expect the early designs of a nation geared to peace to outperform in every field the equipment of countries whose development for years has been based on conquest. But American designers can be relied on soon to take and hold the lead. Appreciating that closed minds and preconceived notions have no place in war they will accept constructive versions of first-hand observers and will design to meet the most logical and soundly based criticisms of machines in actual combat.

Such improvements are already in evidence and under way. There are more and better ones to come, as design of new equipment plus redesign of old swings forcefully to the forefront of the national program.

L. E. Jermy

Graphical Analysis of Planetary Gear Systems—Part II

By Guy J. Talbourdet

Research Division
United Shoe Machinery Corporation

COMPOUND planetary gearing systems, discussed in this article, have two planet pinions in each train. Usually the two planet pinions are attached to each other and revolve about the same centerline, but it is also possible to have them revolve about separate axes and in mesh with each other.

The compound internal planetary system shown in *Fig.* 10 will now be analyzed, considering the case when sun gear S_1 is driven, sun gear S_2 is fixed and arm *A* is driving. Referring to *Fig.* 10 and the nomenclature, since sun gear S_2 is fixed, pitch point p_2 is the instantaneous center of planet pinions P_1 *and* P_2.

> ***CONTINUING the series on planetary gearing analysis by vectors and instant centers, introduced last month, the author presents important examples of compound systems in which one of the sun gears is fixed***

From the geometric conditions of *Fig.* 10, $V_{s1}/V_a = (R_{p2}-R_{p1})/R_{p2}$. But $V_{s1}=\omega_{s1}R_{s1}$ and $V_a=\omega_a R_a$, therefore the speed ratio is $\omega_{s1}/\omega_a=(R_{p2}-R_{p1})R_a/R_{p2}R_{s1}$. Pitch line velocity of engagement of sun gear S_2 and planet pinion P_2 is equal to the relative velocity of arm *A* and pitch circle of sun gear S_2, or $p_2N_2=V_{e2}=\omega_a R_{s2}$.

Since the planet pinions are integral, their pitch line velocities about axis O_p are evidently proportional to their radii, and the pitch line velocity of engagement V_{e1} of planet pinion P_1 with sun gear S_1 becomes $V_{e1}=V_{e2}\,R_{p1}/R_{p2}=R_{s1}\,(\omega_{s1}-\omega_a)$. Angular velocity of planet pinions is V_{e2}/R_{p2} or V_{e1}/R_{p1}; $\omega_p=\omega_a R_{s2}/R_{p2}=R_{s1}\,(\omega_{s1}-\omega_a)/R_{p1}$.

Nomenclature

ω_{s1} = Angular velocity of sun gear S_1
ω_{s2} = Angular velocity of sun gear S_2
ω_{s3} = Angular velocity of sun gear S_3
ω_{p1} = Angular velocity of planet pinion P_1
ω_{p2} = Angular velocity of planet pinion P_2
R_{s1} = Pitch radius of sun gear S_1
R_{s2} = Pitch radius of sun gear S_2
R_{s3} = Pitch radius of sun gear S_3
R_{p1} = Pitch radius of planet pinion P_1
R_{p2} = Pitch radius of planet pinion P_2
R_a = Length of arm *A* from O_s to O_p
O_s = Center of rotation of sun gears
O_p = Center of rotation of planet pinions
p_1 = Pitch point of gear S_1 and pinion P_1
p_2 = Pitch point of gear S_2 and pinion P_2
V_{s1} = Pitch line velocity of sun gear S_1
V_{s2} = Pitch line velocity of sun gear S_2
V_{s3} = Pitch line velocity of sun gear S_3
V_{e1} = Pitch line velocity of engagement of gear S_1 and pinion P_1
V_{e2} = Pitch line velocity of engagement of gear S_2 and pinion P_2
V_{e3} = Pitch line velocity of engagement of gear S_3 and pinion P_2
V_a = Linear velocity of center O_p on arm *A*

To determine the direction of rotation of the planet pinions, it is seen that $V_{e1}=V_{s1}-p_1N_1$ which is in the same direction as sun gear V_{s1}; then the planet pinions must rotate in the opposite direction or counterclockwise. As shown by vector V_{s1}, sun gear S_1 rotates in a clockwise direction.

Here, again, the same procedure is also applicable whether either the sun gear or the arm is fixed, driving or driven. The results of certain of these conditions are given in the engineering data sheets.

Example: To determine the speed ratio, velocity of engagement, and angular velocity of the planet pinions of the above compound internal planetary gearing, *Fig.* 10, when arm A rotates 1200 rpm, $R_{s_1}=6$-inches, $R_{s_2}=6.1$-inch, $R_{p_1}=1.9$-inch, $R_{p_2}=2$-inches and $R_a=4.1$-inch.

Speed ratio is $\omega_{s_1}/\omega_a=4.1(2-1.9)/2\times 6=41/1200$. Angular velocity of driven sun gear S_1 is $41\times 1200/1200=41$ rpm. Pitch line velocity of engagement of pinion P_2 is $V_{e_2}=(1200\times 2\pi\times 6.1)/12=3833$ feet per minute. Pitch line velocity of engagement of pinion P_1 is $V_{e_1}=(3833\times 1.9)/2=3641$ feet per minute. Angular velocity of planet pinions is $(1200\times 6.1)/2=3660$ rpm.

As indicated in the analysis, the driven sun gear rotates in the direction of the driving arm while the planet pinions rotate in the opposite direction. Here, it is interesting to note, the pitch line velocity V_{s_1} of driven sun gear S_1 is $V_{s_1}=\omega_{s_1}R_{s_1}=(41\times 2\pi\times 6)/12=128.8$ feet per minute, while its velocity of engagement is 3641 feet per minute. Friction losses and the dynamic load on the gear teeth would therefore be considerably greater than in simple gear trains.

External System Is Considered

The compound external planetary system shown in *Fig.* 12 will now be analyzed. Sun gear S_1 is driving, sun gear S_2 is fixed and the arm A is driven. Referring to *Fig.* 12 and the nomenclature, since sun gear S_2 is fixed, pitch point p_2 is the instantaneous axis i of planet pinions P_1 and P_2. From the geometric conditions of *Fig.* 12, $V_a/V_{s_1}=R_{p2}/(R_{p_1}-R_{p2})$.

Since $V_a=\omega_a R_a$ and $V_{s_1}=\omega_{s_1}R_{s_1}$, the speed ratio is $\omega_a/\omega_{s_1}=R_{p_2}R_{s_1}/R_a(R_{p_1}-R_{p2})$.

Pitch line velocity of engagement V_{e_1} of planet pinion P_1 with fixed sun gear S_1 is $V_{e_1}=V_{s_1}-(-p_1N_1)$ or $V_{e_1}=R_{s_1}(\omega_{s_1}+\omega_a)$. Since planet pinions P_1 and P_2 are integral, $V_{e_2}=V_{e_1}R_{n_2}/R_{p_1}=R_{s_1}R_{p2}(\omega_{s_1}+\omega_a)/R_{p_1}$. Angular velocity of planet pinions is V_{e_1}/R_{p_1} or $\omega_p=R_{s_1}(\omega_{s_1}+\omega_a)/R_{p_1}$.

To determine the direction of rotation of the planet pinions, it is observed that $V_{e_1}=V_{s_1}-(-p_1N_1)=V_{s_1}+p_1N_1$ which is in the same direction as sun gear S_1. Then the planet pinions rotate in the opposite direction or counterclockwise. As shown by vector V_a, arm A rotates counterclockwise.

Again, the same procedure is applicable if any of the sun gears or the arm is fixed, driving or driven. The results of certain of these conditions are given in the engineering data sheets.

Compound internal and external planetary gearing shown in *Fig.* 14 will now be analyzed—when sun gear S_1 is driving, sun gear S_2 is fixed and arm A is driven. Since sun gear S_2 is fixed, pitch point p_2 is the instantaneous axis i of planet pinions P_1 and P_2. From the geometric conditions of *Fig.* 14, $V_a/V_{s_1}=R_{p2}/(R_{p_1}+R_{p_2})$. Since $V_a=\omega_a R_a$ and $V_{s_1}=\omega_1 R_{s_1}$, the speed ratio is $\omega_a/\omega_{s_1}=R_{p_2}R_{s_1}/R_a(R_{p_1}+R_{p_2})$.

Pitch line velocity of engagement V_{e_1} of planet pinion P_1 with fixed gear S_1 is $V_{e_1}=V_{s_1}-p_1N_1=R_{s_1}(\omega_{s_1}-\omega_a)$. Since planet pinions P_1 and P_2 are integral, $V_{e_2}=V_{e_1}R_{p_2}/R_{p_1}=R_{s_1}R_{p2}(\omega_{s_1}-\omega_a)/R_{p_1}$. Angular velocity of planet pinions is $\omega_p=R_{s_1}(\omega_{s_1}-\omega_a)/R_{p_1}$.

To determine the direction of rotation of the planet pinions it is seen that $V_{e_1}=V_{s_1}-p_1N_1$, which is in the same direction as sun gear S_1. Then the planet pinions rotate in the opposite direction or counterclockwise.

System Has Three Sun Gears

Addition of a third sun gear to the compound internal and external planetary system furnishes a useful mechanism suitable for large reduction ratios. A typical arrangement is shown in *Fig.* 16, the formulas being given on the data sheet.

Example: When sun gear S_1 rotates at 12 rpm, $R_{s_1}=6$ inches, $R_{s_2}=6.2$-inch, $R_{s_3}=1.8$-inch, $R_{p_1}=2$ inches, $R_{p_2}=2.2$-inch, and $R_a=4$ inches, then $V_{s_1}=\omega_{s_1}R_{s_1}=2\pi\times 12\times 6/12=37.7$ feet per minute. The speed ratio between sun gear S_1 and arm A is $\omega_a/\omega_{s_1}=R_{s_1}R_{p2}/R_a(R_{p_2}-R_{p_1})=6\times 2.2/4(2.2—2)=16.5$, and the speed of the arm is $12\times 16.5=198$ rpm. The speed ratio between sun gears S_1 and S_3 is $\omega_{s3}/\omega_{s_1}=2R_{s_1}R_{p2}/R_{s_3}(R_{p_2}-R_{p_1})=2\times 6\times 2.2/1.8\ (2.2—2)=73\frac{1}{3}$, and the speed of sun gear S_3 is $12\times 73\frac{1}{3}=880$ rpm.

The pitch line velocities of tooth engagement are as follows $V_{e_2}=\omega_a R_{s_2}=2\pi\times 198\times 6.2/12=642.77$ feet per minute, $V_{e_1}=R_{s_1}(\omega_{s_1}-\omega_a)=6\times 2\pi(12—198)/12=584.33$ feet per minute, $V_{e_3}=R_{s_3}(\omega_{s_3}-\omega_a)=1.8\times 2\pi(880-198)/12=642.77$ feet per minute. Angular velocity of the planet pinion is $\omega_a R_{s_2}/R_{p_2}$ or $198\times 6.2/2.2=558$ rpm.

Pitch Line Velocities Are Compared

In this example it is worth noting that the pitch line velocity of tooth engagement of sun gear S_1 is 584.33 feet per minute while its pitch line velocity is only 37.7 feet per minute. On the other hand, the pitch line velocity of tooth engagement of sun gear S_3 (642.77 feet per minute) is less than its pitch line velocity, which is $V_{s3}=2V_{s1}R_{p2}/(R_{p_2}-R_{p_1})=2\times 37.7\times 2.2/(2.2-2)=829.4$ feet per minute.

All examples of planetary gearing so far considered have coaxial planet pinions. The mechanism shown in *Fig.* 17 differs from these in having two planet pinions which are not coaxial but which mesh with each other.

In the compound planetary gearing cases considered in this article, one of the sun gears is fixed. In the next article examples will be presented in which two of the sun gears are driving, independently of each other.

Planetary Gearing Systems—II

Compound Internal Planetary Gearing

Sun gear S_1 driving clockwise, sun gear S_2 fixed, R_{S1} less than R_{S2}, arm A driven—Fig. 10

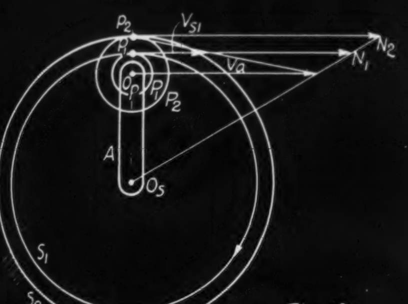


Fig. 10

$$\omega_{s2}=0 \qquad V_{s1}=\omega_{s1}R_{s1}$$

$$\text{Then } V_a=\frac{V_{s1}R_{p2}}{R_{p2}-R_{p1}} \qquad \omega_a=\frac{\omega_{s1}R_{s1}R_{p2}}{R_a(R_{p2}-R_{p1})} \qquad \frac{\omega_a}{\omega_{s1}}=\frac{R_{s1}R_{p2}}{R_a(R_{p2}-R_{p1})}$$

$$V_{e2}=p_2N_2=\omega_aR_{s2} \qquad V_{e1}=R_{s1}(\omega_{s1}-\omega_a) \qquad \omega_p=\frac{R_{s1}}{R_{p1}}(\omega_{s1}-\omega_a).$$

Driven arm *A* rotates clockwise while planet pinions rotate counterclockwise.

When arm *A* is driving and sun gear S_1 is driven the equations for V_{e1}, V_{e2} and ω_p, also the directions of rotation of sun gear S_1 and pinion *P* hold true, but

$$\omega_{s1}=\frac{\omega_aR_a(R_{p2}-R_{p1})}{R_{s1}R_{p2}} \quad \text{and} \quad \frac{\omega_{s1}}{\omega_a}=\frac{R_a(R_{p2}-R_{p1})}{R_{s1}R_{p2}}.$$

Sun gear S_1 driving clockwise, sun gear S_2 fixed, R_{S1} greater than R_{S2}, arm A driven—Fig. 11

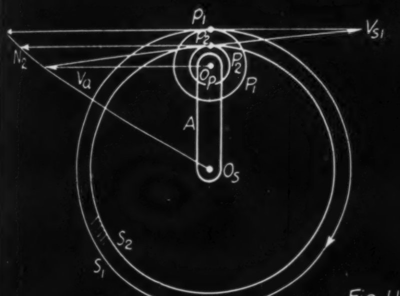


Fig. 11

$$\omega_{s2}=0 \qquad V_{s1}=\omega_{s1}R_{s1}$$

$$\text{Then } V_a=\frac{V_{s1}R_{p2}}{R_{p1}-R_{p2}} \qquad \omega_a=\frac{\omega_{s1}R_{s1}R_{p2}}{R_a(R_{p1}-R_{p2})} \qquad \frac{\omega_a}{\omega_{s1}}=\frac{R_{s1}R_{p2}}{R_a(R_{p1}-R_{p2})}.$$

$$V_{e2}=p_2N_2=\omega_aR_{s2} \qquad V_{e1}=R_{s1}(\omega_{s1}-\omega_a) \qquad \omega_p=\frac{R_{s1}}{R_{p1}}(\omega_{s1}-\omega_a).$$

Driven arm *A* rotates counterclockwise while planet pinions rotate clockwise.

When arm *A* is driving counterclockwise and sun gear S_1 is driven the foregoing equations for V_{e1}, V_{e2} and ω_p hold true, but

$$\omega_{s1}=\frac{\omega_aR_a(R_{p1}-R_{p2})}{R_{s1}R_{p2}} \quad \text{and} \quad \frac{\omega_{s1}}{\omega_a}=\frac{R_a(R_{p1}-R_{p2})}{R_{s1}R_{p2}}.$$

Driven sun gear S_1 and planet pinions rotate clockwise.

When sun gear S_2 is driving member and sun gear S_1 is fixed, the vector diagrams will be similar to *Fig.* 10.

Compound External Planetary Gearing

Sun gear S_1 driving clockwise, sun gear S_2 fixed, R_{S1} less than R_{S2}, arm A driven—Fig. 12

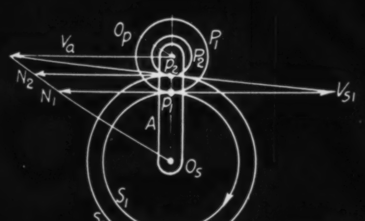


Fig. 12

$$\omega_{s2}=0 \qquad V_{s1}=\omega_{s1}R_{s1}.$$

$$\text{Then } V_a=\frac{V_{s1}R_{p2}}{R_{p1}-R_{p2}} \qquad \omega_a=\frac{V_{s1}R_{p2}}{R_a(R_{p1}-R_{p2})} \qquad \frac{\omega_a}{\omega_{s1}}=\frac{R_{s1}R_{p2}}{R_a(R_{p1}-R_{p2})}.$$

$$V_{e2}=p_2N_2=\omega_aR_{s2} \qquad V_{e1}=V_{s1}+p_1N_1=R_{s1}(\omega_a+\omega_{s1})=\frac{\omega_aR_{s2}R_{p1}}{R_{p2}}$$

$$\omega_p=\frac{\omega_aR_{s2}}{R_{p2}}$$

Driven arm *A* and planet pinions rotate counterclockwise.

When arm *A* is driving, sun gear S_2 is fixed and sun gear S_1 is driven, the foregoing equations for V_{e1}, V_{e2} and ω_p hold true, but

$$\omega_{s1}=\frac{\omega_aR_a(R_{p1}-R_{p2})}{R_{s1}R_{p2}} \quad \text{and} \quad \frac{\omega_{s1}}{\omega_a}=\frac{R_a(R_{p1}-R_{p2})}{R_{s1}R_{p2}}.$$

Planet pinions rotate in direction of arm *A* while sun gear S_2 rotates in opposite direction.

Sun gear S_1 driving clockwise, sun gear S_2 fixed, R_{S1} greater than R_{S2}, arm A driven—Fig. 13

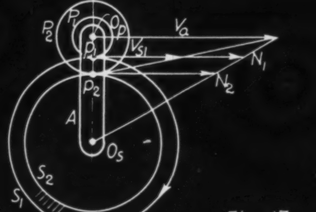


Fig. 13

$$\omega_{s2}=0 \qquad V_{s1}=\omega_{s1}R_{s1}$$

$$\text{Then } V_a=\frac{V_{s1}R_{p1}}{R_{p1}-R_{p2}} \qquad \omega_a=\frac{V_{s1}R_{p1}}{R_a(R_{p1}-R_{p2})} \qquad \frac{\omega_a}{\omega_{s1}}=\frac{R_{s1}R_{p1}}{R_a(R_{p1}-R_{p2})}.$$

$$V_{e2}=p_2N_2=\omega_aR_{s2} \qquad V_{e1}=V_{s1}-p_1N_1=R_{s1}(\omega_{s1}-\omega_a)=\frac{\omega_aR_{s2}R_{p1}}{R_{p2}} \qquad \omega_p=\frac{\omega_aR_{s2}}{R_{p2}}$$

Driven arm *A* and planet pinions rotate clockwise.

When arm *A* is driving, sun gear S_2 is fixed and sun gear S_1 is driven, the foregoing equations for V_{e1}, V_{e2} and ω_p hold true and the directions of rotation of driven sun gear S_1 and planet pinions are clockwise, but

$$\omega_{s1}=\frac{\omega_a(R_{p1}-R_{p2})}{R_{s1}R_{p1}} \quad \text{and} \quad \frac{\omega_{s1}}{\omega_a}=\frac{R_a(R_{p1}-R_{p2})}{R_{s1}R_{p1}}.$$

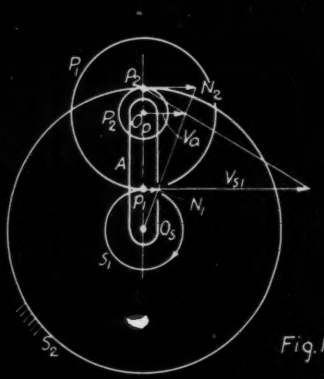


Fig.14

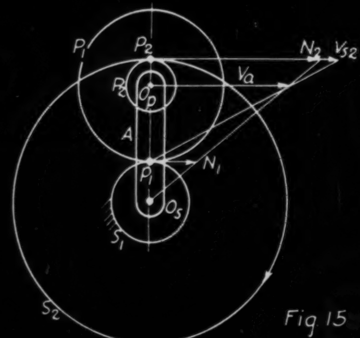


Fig 15

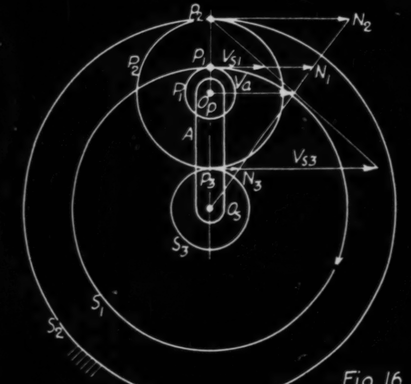


Fig 16

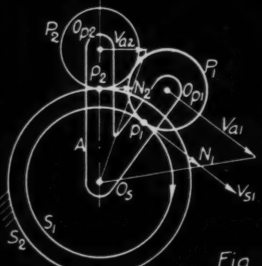


Fig 17

Compound Internal and External Planetary

Sun gear S_1 driving clockwise, internal sun gear S_2 fixed, arm A driven—Fig. 14

$$\omega_{s2}=0 \qquad V_{s1}=\omega_{s1}R_{s1}.$$

Then $V_a=\dfrac{V_{s1}R_{p2}}{R_{p1}+R_{p2}}$ $\quad \omega_a=\dfrac{V_{s1}R_{p2}}{R_a(R_{p1}+R_{p2})}$ $\quad \dfrac{\omega_a}{\omega_{s1}}=\dfrac{R_{s1}R_{p2}}{R_a(R_{p1}+R_{p2})}.$

$$V_{e1}=V_{s1}-p_1N_1=R_{s1}(\omega_{s1}-\omega_a) \qquad V_{e2}=0-p_2N_2=-\omega_aR_{s2}$$

$$\omega_p=\frac{\omega_aR_{s2}}{R_{p2}}=\frac{R_{s1}(\omega_{s1}-\omega_a)}{R_{p1}}$$

Driven arm rotates clockwise and planet pinions rotate counterclockwise. When arm A is driving clockwise, sun gear S_2 is fixed and sun gear S_1 is driven, the foregoing equations for V_{e1}, V_{e2} and ω_p hold true, but

$$\omega_{s1}=\frac{V_a(R_{p1}+R_{p2})}{R_{s1}R_{p2}} \quad \text{and} \quad \frac{\omega_{s1}}{\omega_a}=\frac{R_a(R_{p1}+R_{p2})}{R_{s1}R_{p2}}$$

Driven sun gear S_1 rotates clockwise and planet pinions rotate counterclockwise.

Sun gear S_1 fixed, internal sun gear S_2 driving clockwise, arm A driven—Fig. 15

$$\omega_{s1}=0 \qquad V_{s2}=\omega_{s2}R_{s2}$$

Then $V_a=\dfrac{V_{s2}R_{p1}}{R_{p1}+R_{p2}}$ $\quad \omega_a=\dfrac{V_{s2}R_{p1}}{R_a(R_{p1}+R_{p2})}$ $\quad \dfrac{\omega_a}{\omega_{s2}}=\dfrac{R_{s2}R_{p1}}{R_a(R_{p1}+R_{p2})}$

$$V_{e1}=0-p_1N_1=-\omega_aR_{s1} \qquad V_{e2}=V_{s2}-p_2N_2=R_{s2}(\omega_{s2}-\omega_a) \qquad \omega_p=\frac{\omega_aR_{s1}}{R_{p1}}$$

Driven arm A and planet pinions rotate clockwise.
When arm A is driving clockwise, sun gear S_1 is fixed and sun gear S_2 is driven, the foregoing equations for V_{e1}, V_{e2} and ω_p hold true, but

$$\omega_{s2}=\frac{V_a(R_{p1}+R_{p2})}{R_{s2}R_{p1}} \quad \text{and} \quad \frac{\omega_{s2}}{\omega_a}=\frac{R_a(R_{p1}+R_{p2})}{R_{s2}R_{p1}}.$$

Driven sun gear S_2 and planet pinions rotate clockwise.

Sun gear S_1 driving clockwise, sun gear S_2 fixed, arm A and sun gear S_3 driven—Fig. 16

$$V_{s1}=\omega_{s1}R_{s1} \qquad V_{s2}=0.$$

Then $V_a=\dfrac{V_{s1}R_{p2}}{R_{p2}-R_{p1}}$ $\quad \omega_a=\dfrac{\omega_{s1}R_{s1}R_{p2}}{R_a-(R_{p2}-R_{p1})}$ $\quad \dfrac{\omega_a}{\omega_{s1}}=\dfrac{R_{s1}R_{p2}}{R_a(R_{p2}-R_{p1})}.$

Also, $V_{s3}=\dfrac{2V_{s1}R_{p2}}{R_{p2}-R_{p1}}$ $\quad \omega_{s3}=\dfrac{2\omega_{s1}R_{s1}R_{p2}}{R_{s3}(R_{p2}-R_{p1})}$

$$\frac{\omega_{s3}}{\omega_{s1}}=\frac{2R_{s1}R_{p2}}{R_{s3}(R_{p2}-R_{p1})}.$$

$$V_{e2}=0-p_2N_2=-\omega_aR_{s2} \qquad V_{e1}=V_{s1}-p_1N_1=R_{s1}(\omega_{s1}-\omega_a)$$

$$V_{e3}=V_{s3}-p_3N_3=R_{s3}(\omega_{s3}-\omega_a) \qquad \omega_p=\frac{-\omega_aR_{s2}}{R_{p2}}.$$

Driven sun gear S_3 and arm A rotate clockwise and planet pinions rotate counterclockwise.

Compound Planetary with Idler Planet Pinion

Sun gear S_1 driving clockwise, sun gear S_2 fixed, R_{S1} less than R_{s2}, arm A driven—Fig. 17

$$\omega_{s2}=0 \qquad V_{s1}=\omega_{s1}R_{s1}$$

Then $\omega_a=\dfrac{\omega_{s1}R_{s1}}{R_{s1}+R_{s2}}$ $\quad V_e=V_{s1}-p_1N_1=R_{s1}(\omega_{s1}-\omega_a).$

$$\omega_{p1}=\frac{R_{s1}}{R_{p1}}(\omega_{s1}-\omega_a) \qquad \omega_{p2}=\frac{R_{s1}}{R_{s2}}(\omega_{s1}-\omega_a)$$

Driven arm A and planet pinion P_2 rotate clockwise while planet pinion P_1 rotates counterclockwise.

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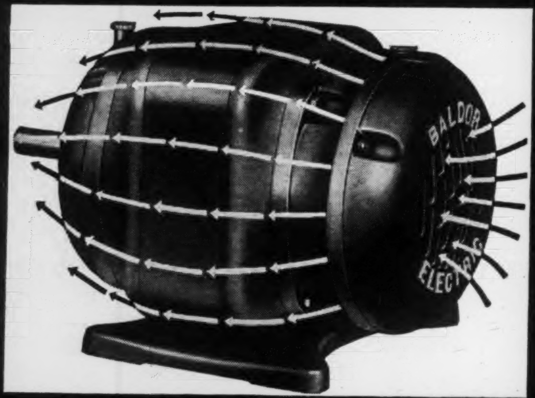

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" . . . to improve endurance"

To the Editor:

In several of your interesting articles, shotblasting and grinding of heat treated springs have been discussed as methods to improve the surface characteristics for endurance.

As I am dealing now with such problems, I would appreciate some information on this subject. Because special alloy steels are not available under present emergency conditions for flat flexural springs of about ⅛-inch by 3 inches by 20 inches, working in reversed bending at 2000 cycles per minute, plain hot-rolled carbon steels are indicated. What would be the best carbon content and is there a special heat treatment for fatigue loading?

Which of the following treatments after heat treatment is best from a technical as well as an economical point of view: Sandblasting, steel shotblasting, sandblasting to remove the surface 1/64-inch followed by shotblasting, or grinding?

Where could I get information on specifications for these operations such as number of shot, pressure, time, angle at which operated, etc?

—L. M. DeKanski
New York City

" . . . shotblasting is beneficial"

To the Editor:

Replying to Dr. DeKanski's letter I would like to comment as follows:

With regard to the application of flat flexural springs in reversed bending, I see no reason why the usual heat-treated, carbon spring steel of about one per cent carbon may not be used provided that the alternating stresses are kept well below the endurance limit of the material, stress concentration and condition of surface being taken into account. It is also assumed that the springs are protected from corrosion.

Regarding the relative value of the various treatments mentioned, I have no actual data on shotblasting of leaf springs though I understand that this process yields beneficial results. I would think that steel shotblasting would probably give better results than sandblasting, while sandblasting to remove the surface layer followed by shotblasting might be even better, possibly even better than grinding. However, this is only an opinion and further test data will be required for a complete picture. We do know that by shotblasting it is possible to raise the endurance limits of helical springs to values approximating those to be expected for ground

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4 SEGREGATION:
Identify, classify and segregate scrap and supervise its handling to avoid contamination. This will increase its value.

Provide separate containers, clearly marked, for each class of scrap material.

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Dismantle discarded equipment promptly into its components—electrical, fastenings, lumber, etc.—so that these parts may be utilized or scrapped.

Sort blanks, short ends, cut-downs, clippings, etc., for possible reuse for smaller parts made in the same or other departments.

Recover and reclaim used cutting oils, lubricants, surplus paints and spray finishes.

Sort sweepings and miscellaneous waste to recover scrap values.

5 Constant reminders in the form of posters, illustrations of right and wrong methods, pay envelope enclosures, house organ publicity, etc., are potent aids to the conservation program.

6 Release for scrap, obsolete engravings, electrotypes, and standing types for catalogs, forms and advertising material.

7 Inspect all refuse to detect avoidable waste and excessive rejections. Educate production executives to correct such conditions at the source.

8 For information and assistance on special phases of conservation and salvage communicate with Industrial Salvage Section, Conservation Division, War Production Board, 9th Floor, Washington Gas Light Building, Washington, D. C., or with nearest regional office

The metallurgical experience of our technical staff is available to aid you in these and other technical phases of metal salvage.

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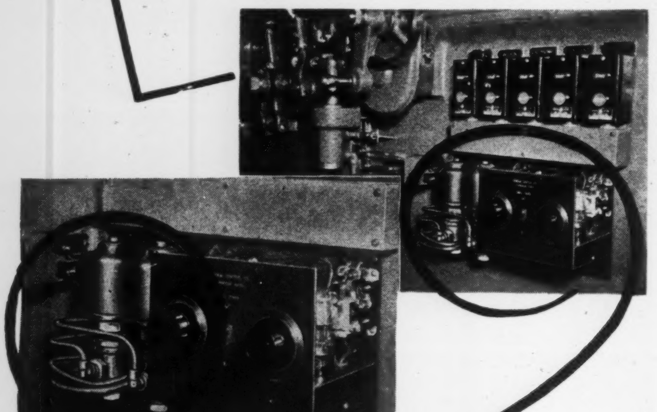

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and polished specimens of the same material, tested in torsion.

F. P. Zimmerli of Barnes-Gibson-Raymond Div. of Associated Spring Corp., Detroit has had considerable experience with shotblasting of springs and some data on this were given in his article published in MACHINE DESIGN, November, 1940.

—A. M. WAHL
Westinghouse Elec. & Mfg. Co.

" . . . quotes low physicals"

To the Editor:

Our engineers do not agree entirely with Mr. Delmonte in his article on high density impregnated wood, published in your July issue. They state:

This article asserts that a wood impregnated with alcohol-soluble phenolic resin pressed at 2000 to 3000 pounds per square inch gives a product where the "wood acts more as a filler due to its having been crushed by the high laminating pressures". It is acknowledged that Pregwood, a product of this company, is a high-density, laminated wood produced under high pressure. However, the process used is not such that the physical values of the wood are impaired. The author of the article quotes very low physical values for his high density wood. We obtained the following:

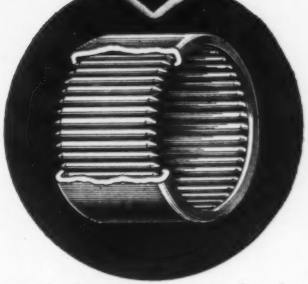
Specific Gravity	1.32 to 1.37
Tensile Strength	30,000 to 45,000 psi
Compression	20,000 to 28,000 psi
Modulus of Rupture	35,000 to 40,000 psi
Modulus of Elasticity	2,700,000 to 6,000,000 psi
Izod Impact	5 to 12
Shear	7,000 to 11,000 psi on perpendicular lamination and 4,700 psi parallel to laminations.

These tests are in accordance with Army Air Corps Specification 15065.

The author places stress on the fact that water-soluble varnish is different from an alcohol-soluble varnish. The degree of solubility of varnish in any solvent is not a good criterion of type of varnish. Varnishes are soluble in water and in alcohol in varying degrees. Some varnishes are 100 per cent soluble in both water and alcohol. There are alcohol-soluble varnishes which do not penetrate wood and others which when the proper technique is used will penetrate the wood. Apparently the author either did not use the correct alcohol-soluble varnish or the correct technique. In general it is found that water-soluble varnishes tend to produce a more brittle product than alcohol-soluble type. Water-soluble varnishes also have inferior keeping qualities. The author gives minimum per cent water absorption as about 14. This is rather high. However, the value depends on the test method used.

Data is given on various species of wood. When high-density materials are produced from these woods the differences present in the original woods disappear. When high density wood is properly produced there is no destructive crushing of the fibers. The cell walls are coated with resin and the pressure produces intimate contact of these walls such that the fibers are fused together. A product of this sort has a shear value and a tensile strength across the grain which is all out

THE "ROUTINE PART" IN WAR MATERIEL



INSPECTION keeps a manufacturer "on his metal" these days. Changes come thick and fast in war production. That tank rolling off the assembly line may be a redesign...the last shipment of machine parts may have been supplied by a newcomer to the Victory program.

But there's a routine part in most war materiel—the Torrington Needle Bearing. As new type equipment comes out of production for approval, Chief Inspectors are increasingly aware of the Needle Bearing's presence in the finished assembly. Long since "changed over" to production-for-war, this unusual bearing is meeting every new requirement of industry today.

Its small size, for example, is conserving space and critical materials. Its remarkable ease of installation is cutting assembly time...its simplified design is eliminating extra parts and assembly steps...its low coefficient of friction assuring smooth performance ...high capacity and efficient lubrication reducing the need for replacement or maintenance attention—all vital wartime needs, speeding production.

In its adaptability to the latest type fighting machines, as well as the equipment that assembles them, the Needle Bearing is again demonstrating its unique advantages—and in applications where these advantages mean more today than ever.

FOR INFORMATION *concerning capacities and sizes, send for Catalog No. 109. Or consult a Torrington engineer. He is an expert in adapting the Needle Bearing's advantages to specific problems.*

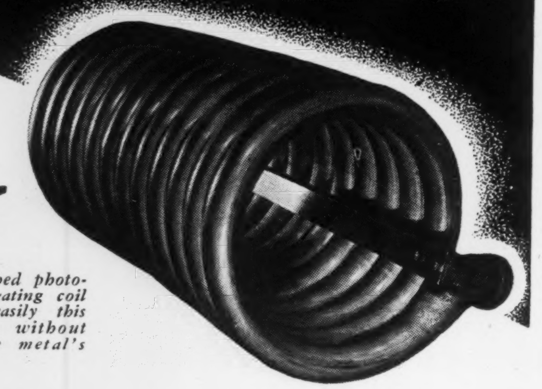
LET'S GO! U.S.A. KEEP 'EM FLYING!

THE TORRINGTON COMPANY
TORRINGTON, CONN., U. S. A. • *Est. 1866*
Makers of Needle and Ball Bearings
New York Boston Philadelphia Detroit
Cleveland Seattle Chicago Los Angeles
San Francisco Toronto London, England

TORRINGTON NEEDLE BEARING

Every feature fills a wartime need

Answers
to YOUR questions about
WELDED STAINLESS TUBING



This unretouched photograph of a heating coil shows how easily this tubing bends, without damaging the metal's structure.

Why WELDED tubing?—Because the uniform wall thickness of welded tubing permits the use of lighter gauges where strength is needed. There are no thin spots to "wear through" first. The use of lighter gauge tubing saves weight, conserves metal, makes fabricating easier.

Why STAINLESS tubing?—Because it takes *Stainless* to lick tough heat and corrosion problems. *Stainless* provides a bright, easy-to-clean finish that helps to keep maintenance down.

Is it EASY TO FABRICATE?—Yes! Tube shapes are *natural* design units. Parts can often be finish formed by merely swaging, expanding, tapering, etc. Because of its ductility and uniform structure, Carpenter Welded Stainless Tubing is easy to bend, cut or weld.

THE BENDING TEST shows the strength of the weld. On this test piece from a regular production run, the metal was "bent double" along the weld and no breakage occurred.

ANSWERS to some of your other questions can be found in Carpenter's 16-page Welded Stainless Tubing Data Book. A note on your company letterhead will start a copy on its way to you.

- *Carpenter Welded Stainless Tubing meets U. S. Army and Navy specifications.*
- *Each length is 100% hydrostatically tested.*

THE CARPENTER STEEL COMPANY
Welding Alloy Tube Division, Kenilworth, N. J.

Carpenter
WELDED
STAINLESS TUBING

of proportion to the increase in density; whereas the specific tensile strength remains essentially the same as that of the original wood.

—J. R. White
The Formica Insulation Co.

" . . . need simple treatment"

To the Editor:

Referring to the comments on my article on impregnated woods, it is our experience that, when the amount of resin present passes a certain percentage, the material will behave more like a molding compound even to the extent of disintegrating under the flow of the resin binder. In connection with the properties reported I would like to point out that our tests were performed upon samples in which two layers had the grain running lengthwise and one layer had the grain running crosswise.

If a technique were developed whereby wood can obtain the benefits of resin impregnation by a simple immersion treatment rather than by special processes this would be of great interest to bonded plywood fabricators. Hence, it is the feeling of the writer that there is a definite place for water-soluble types of phenolics. Their greater brittleness with respect to alcohol types is a well known fact. As discussed in the article the per cent of water absorbed is not as significant as the per cent of dimensional change.

—John Delmonte, *Technical Director*
Plastics Industries Technical Institute

ASSETS to a BOOKCASE

Production Engineering—Jig and Tool Design

By E. J. H. Jones, works manager of the Associated Equipment Co. Ltd.; published by Chemical Publishing Co. Inc., Brooklyn; 304 pages, 5½ by 8½ inches, clothbound; available through Machine Design, *$5.00 postpaid.*

Full responsibility for both engineering design and designing for production is rarely vested in one individual. Of necessity the engineering designer cannot be expected to be as familiar with the scope and limitations of modern machine tools as the man who has to use them, but a sound background knowledge of the general principles of jig and tool design is today just as important as the other branches of the machine designer's stock-in-trade. Much of this knowledge comes from experience, some of it perhaps bitter. Difficulty of formulating general principles makes the study of this subject more of a case method than a scientific approach. This book, originally published in England, contains a large number of practical examples of jigs and fixtures together with explanations of the reasons for so designing them, and as much in the way of basic principles as can be formulated. Because of its highly practical flavor the book will com-

FASTER *Blueprinting* MACHINES KEEP WAR PRODUCTION HUMMING

Guns, tanks, planes and warships on the nation's drafting tables deal no immediate crushing blows to our enemies . . . there is a gap between these engineering drawings and the production line . . . however, Blueprints at 30 feet per minute effectively bridge this gap, making war production hum full blast, 24 hours every day.

Pease Continuous Blueprinting Machines turn out finished prints faster, better and cheaper . . . finished prints that lie flatter, are more contrasty, have cleaner white lines and darker blue backgrounds . . . finished prints that insure a saving in time and money because of these outstanding features:

• **Sliding "Vacuum-like" Contact** (illustrated) • **Three Speed Lamp Control,** provides operation at 10, 15 or 20 amperes, does away with running speed and dryer heat changes • **Actinic "No-break" Arc Lamps** burn for 45 minutes without breaking arc, resume instantaneously • **Horizontal Water Wash** floats prints free from tension and prevents wrinkles, stains, bleeding • **Quick Change Chemical Applicator System** allows change from blueprints to negatives or vice versa in 30 seconds, very economical • **Rapid Drying Drums,** heated by gas or electricity and thermostatically controlled.

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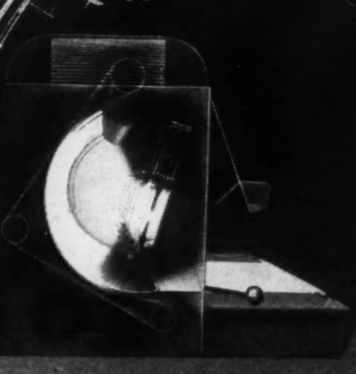
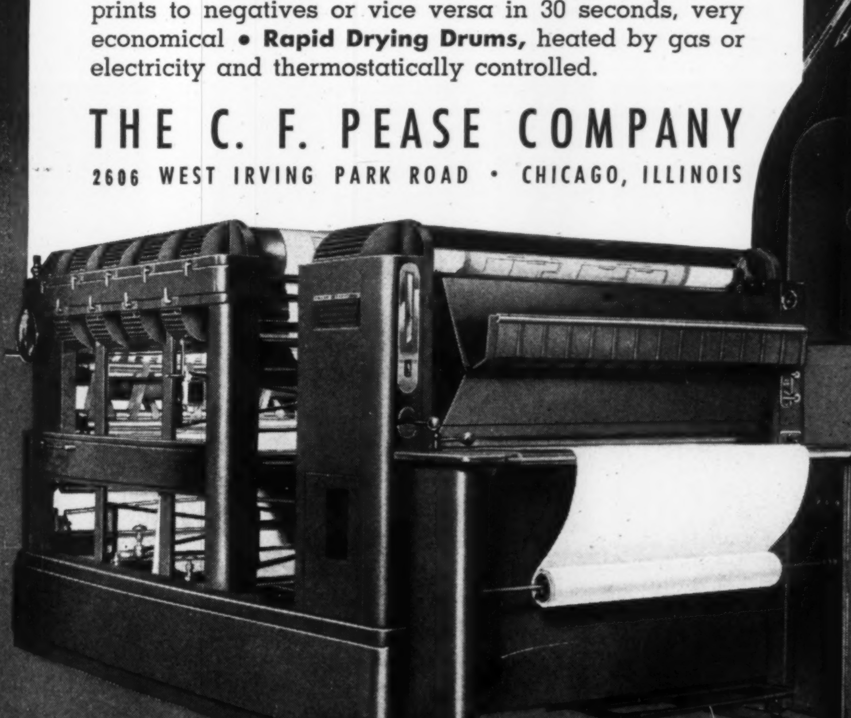


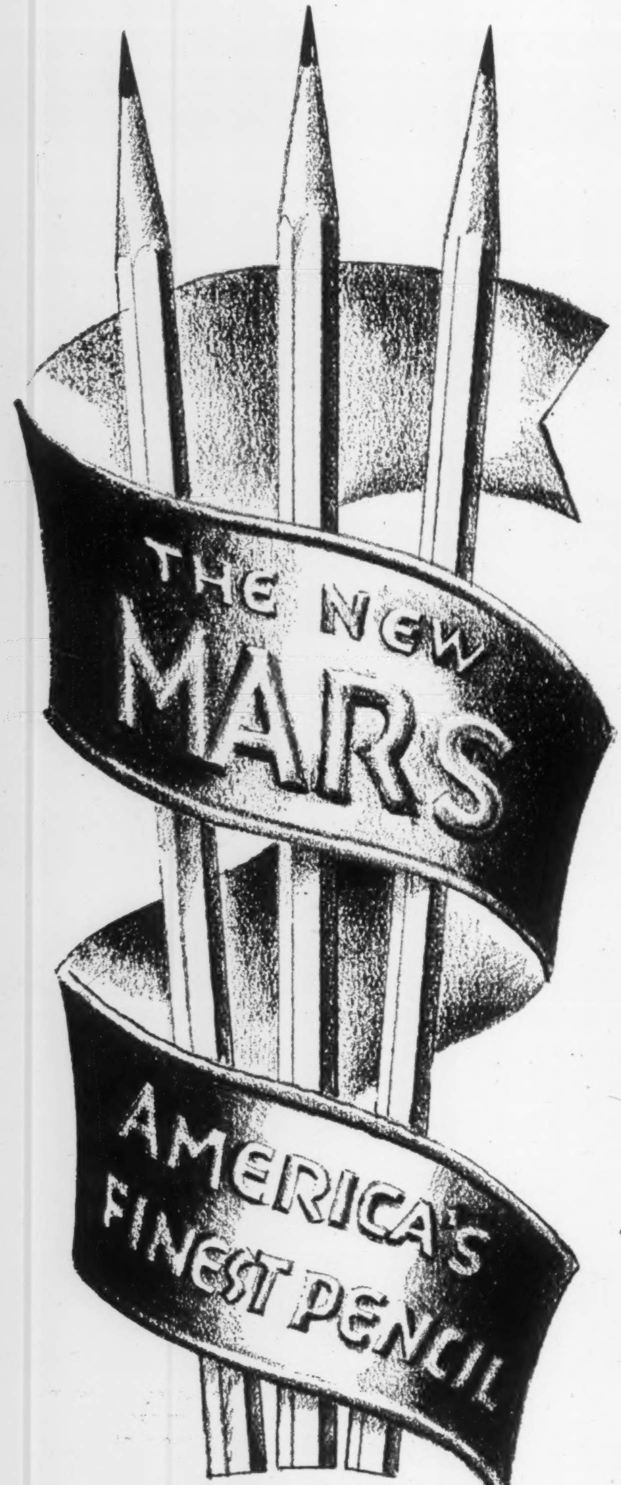
SLIDING CONTACT

Smooths out inequalities in all tracings, gives 24¾" of uninterrupted exposure area and approximates vacuum frame contact. An endless belt assures even contact and, since paper and tracings are never stationary in respect to the glass, errors are impossible. Imperfections or dirt marks cannot print a number "3" as a "5," "8," "8," "9," etc.



Pease Model "22"
Continuous Blueprinting, Washing, Developing and Drying Machine. Production Speed—30 feet per minute.

Blueprinting Machines A TYPE AND SIZE FOR EVERY REQUIREMENT INCLUDING DIRECT PROCESS PRINTING



J·S·STAEDTLER·INC·NEW YORK

NATIONAL DISTRIBUTORS:
KEUFFEL & ESSER CO.
NEW YORK

mend itself to machine designers and executives seeking to understand the problems of tool engineering and to improve their own technique in the light of tooling requirements.

□ □ □

Elementary Structural Analysis and Design

By L. E. Grinter, vice president and dean of the graduate school, Illinois Institute of Technology; published by The Macmillan Co., New York; 383 pages, 6 by 9¼ inches, clothbound; available through Machine Design, $3.75 *postpaid.*

Current rapid expansion of plant facilities has required many mechanical designers to turn their efforts toward structural design. For those to whom design considerations, materials used and methods of attachment found in structural design are unfamiliar, this book can be highly recommended. Prepared primarily for non-civil engineers, the book places comparatively little emphasis on theory and concentrates on design considerations. Illustrations of construction details are plentifully provided and many worked examples show typical stress analysis solutions. In visualizing the behavior of structures under load, the sketches showing the shape assumed by typical structures as they fail will be found most helpful.

While two-thirds of the book is devoted to steel construction because of its importance in industrial buildings, adequate space is also given to concrete and timber construction, of increasing importance because of the diversion of steel into war machines and ships. Abbreviated specifications from the construction codes for steel, welding and concrete design are included in a final chapter.

□ □ □

Procedure Handbook of Arc Welding Design and Practice

Published by The Lincoln Electric Co., Cleveland; 5⅝ by 8¾ inches, 1308 pages, bound in semi-flexible imitation leather; available through Machine Design, $1.50 *postpaid in U. S. A.*

Containing as much information on the science and practice of welding as it is physically possible to accommodate between the covers of a normal-sized book, the seventh edition of this well-known handbook adheres to the style set by preceding editions. Of particular interest to designers is Part VI on welded steel construction in machine design which alone covers about two hundred pages. In addition to basic design information many illustrations of typical construction details are given, and in another section a comprehensive series of photographs highlights recent applications of welding technique.

New information is given on welding symbols, allowable stresses, preheating for welding, stress relieving, general metallurgical characteristics of metals and alloys, weldability of aluminum alloys, tubular construction, appearance and styling, etc.

O E M Photos by Palmer in an Allegheny Ludlum plant

Save . . TO PRODUCE MORE

★ *The nation needs scrap iron and steel—millions of extra tons of it this year. Make your clean-up complete, both in the plant and at home. Subject every pound of idle metal to the searching question: "Is it absolutely essential that we keep this?"*

But don't stop there! Rounding up the scrap and instituting more thorough salvage methods are only part of the job of conserving the nation's resources. Start at the beginning and make better use of *new* steel . . . aim to get more finished products out of it, with less waste.

That is particularly necessary with electric-furnace steels, and the critical alloys they contain. There are many ways to save. Both stainless and tool steels can be more efficiently selected and better used, to step up production and cut down the amount of rejects and spoilage. The substitution of lower alloys, and of standard analyses, sizes or finishes instead of special ones, all offer good opportunities to save.

Right now, do your share to increase the nation's scrap stockpile. And for the duration, avoid waste in all its forms—*make every pound of steel and alloys go as far as possible.* There will be problems involved, but not insoluble ones. Call on our Technical Staff to help you.

AL
STEEL FOR THE NATION'S WELFARE

Allegheny Ludlum
STEEL CORPORATION
GENERAL OFFICES: PITTSBURGH, PENNSYLVANIA

PROMOTED

on merit

32 YEARS' DISTINGUISHED SERVICE

One advancement after another — covering more than three decades — has built up Allen's capacity for this emergency. Plant equipment and product-improvement have "worked their way up" to the top.

Training *started in 1910* has qualified this organization to maintain manufacturing standards under war pressure. Quality has not been demoted in the all-out production-drive.

On their RECORD in the hollow screw field, "Allens" have been promoted to First-in-Demand. Their rank is recognized as the earned reward for Distinguished Service.

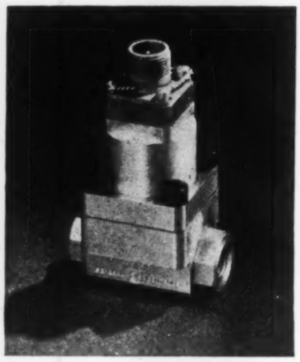
Your local Allen Distributor will secure for you the largest shipments compatible with your priorities and our intensified production-effort.

THE ALLEN MFG. COMPANY
HARTFORD, CONNECTICUT, U. S. A.

New PARTS AND MATERIALS

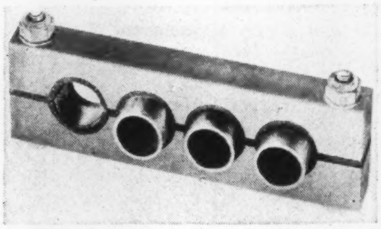
Portable Electric-Magnetic Valves

PORTABLE electric magnetic valves which resist vibration and change of motion, as well as operate in any position, are announced by General Controls Co., Glendale, Calif. Designed for operation on moving equipment such as trucks, busses, tanks, airplanes, railway equipment, boats and all portable or vibrating machinery and engines, the new valves handle all liquids, gases and vapors at pressures from 0 to 1500 pounds per square inch or more. The standard line includes normally open, normally closed, and relief types supplemented by 3-way and 4-way selector valves. They are known as PV series portable electric-magnetic valves.



Supports Utilize Plastic

BY EMPLOYING a plastic block with a thin strip of adelite synthetic rubber compound instead of a thick block of rubber or rubber compound, the new plastic multiple line support for aircraft plumbing introduced by Adel Precision Products Corp., Burbank, Calif., reduces rubber content by from 88 to 94 per cent. Depending on size of airplane, from 40 to 250 supports are used to carry fuel, oil and hydraulic tubing and electric conduits. They batten down from two to thirty



MINERAL OIL. Most tracing papers are treated with some kind of oil. Mineral oil is physically unstable, tends to "drift", never dries completely. Papers treated with mineral oil pick up dust, lose transparency with age.

VEGETABLE OIL, chemically unstable, oxidizes easily. Papers treated with vegetable oil become rancid and brittle, turn yellow and opaque with age.

ALBANITE is a crystal-clear synthetic solid, free from oil and wax, physically and chemically inert. Because of this new stabilized transparentizing agent Albanene is unaffected by harsh climates—will not oxidize with age, become brittle or lose transparency.

A crystal-clear synthetic solid age-proofs this tracing paper

No oil, no wax—but a remarkable new transparentizing agent developed in the K&E laboratories—produces this truly permanent tracing paper! ALBANENE is made of 100% long fiber pure white rags—treated with *ALBANITE*—a new crystal-clear synthetic solid, physically and chemically inert. ALBANENE will not oxidize, become brittle or lose transparency with age.

Equally important, ALBANENE has a fine hard "tooth" that takes ink or pencil beautifully and erases with ease . . . a high degree of transparency that makes tracing simple, produces strong sharp blueprints . . . extra strength to stand up under constant corrections, filing and rough handling. ALBANENE has *all* the working qualities you've always wanted—and *it will retain all these characteristics indefinitely.*

Try ALBANENE yourself on your own drawing board. Ask your K&E dealer, or write us, for an illustrated brochure and a generous working sample.

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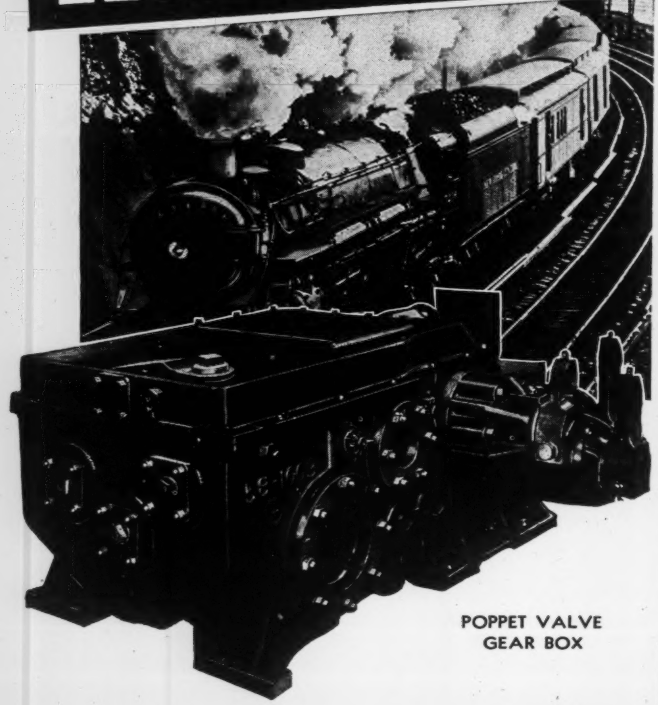
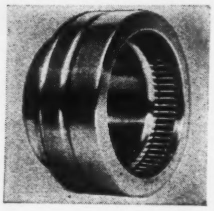
REG. U. S. PAT. OFF.
THE STABILIZED TRACING PAPER

200,000 MILES *and not a bearing failure for* RBC CYCLOPS BEARINGS





RBC CYCLOPS

Bearings are used in the Franklin System of Steam Distribution, developed and manufactured by the Franklin Railway Supply Co., Inc., which increases "train load speed" capacity up to 44%.

RBC CYCLOPS Bearings are put to a gruelling test in such an application and even after 200,000 miles they show no signs of bearing wear.

The many and varied uses of RBC Roller Bearings prove their ability to do the job. Consult RBC engineers on your job.

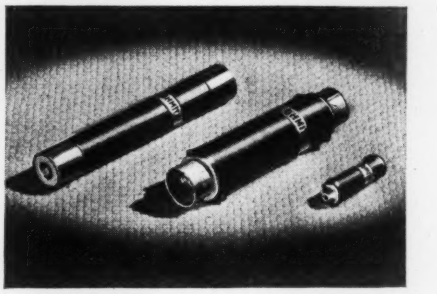
Send for Catalog with Complete Engineering Data

ROLLER BEARING COMPANY *of* AMERICA
TRENTON . . . . NEW JERSEY

lines per unit, protecting them against vibration and at the same time grounding them against static interfering with radio communication. The new supports are available in over 2000 types and sizes and are easily interchangeable with previous supports furnished by the company to the aircraft industry. While frankly admitting that the new plastic supports cannot be expected to equal their previous models, the company states that tests show the plastic assemblies provide ample service dependability for most installations.

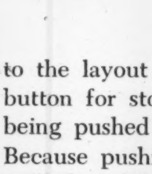
Ferrule Type Resistors Offered

DESIGNED for easy interchangeability without use of tools, The Ohmite Mfg. Co., 4835 Flournoy street, Chicago, has introduced its new ferrule type resistors, particularly applicable in the Navy, Signal Corps, on Army aircraft and on railroads. An even winding of resistance wire on a ceramic core is protected by vitreous enamel coating, and the wire is terminated on metal bands or ferrules permitting mounting in fuse clips. Ferrules are cup, sleeve, or cartridge type. Special ceramic cores with special coating will withstand the temperature shock test of repeated immersions alternately from ice cold water to hot water. Also available are protective coatings which pass salt water immersion tests. Units in accordance with Navy specifications, in wide range of sizes, can be supplied.

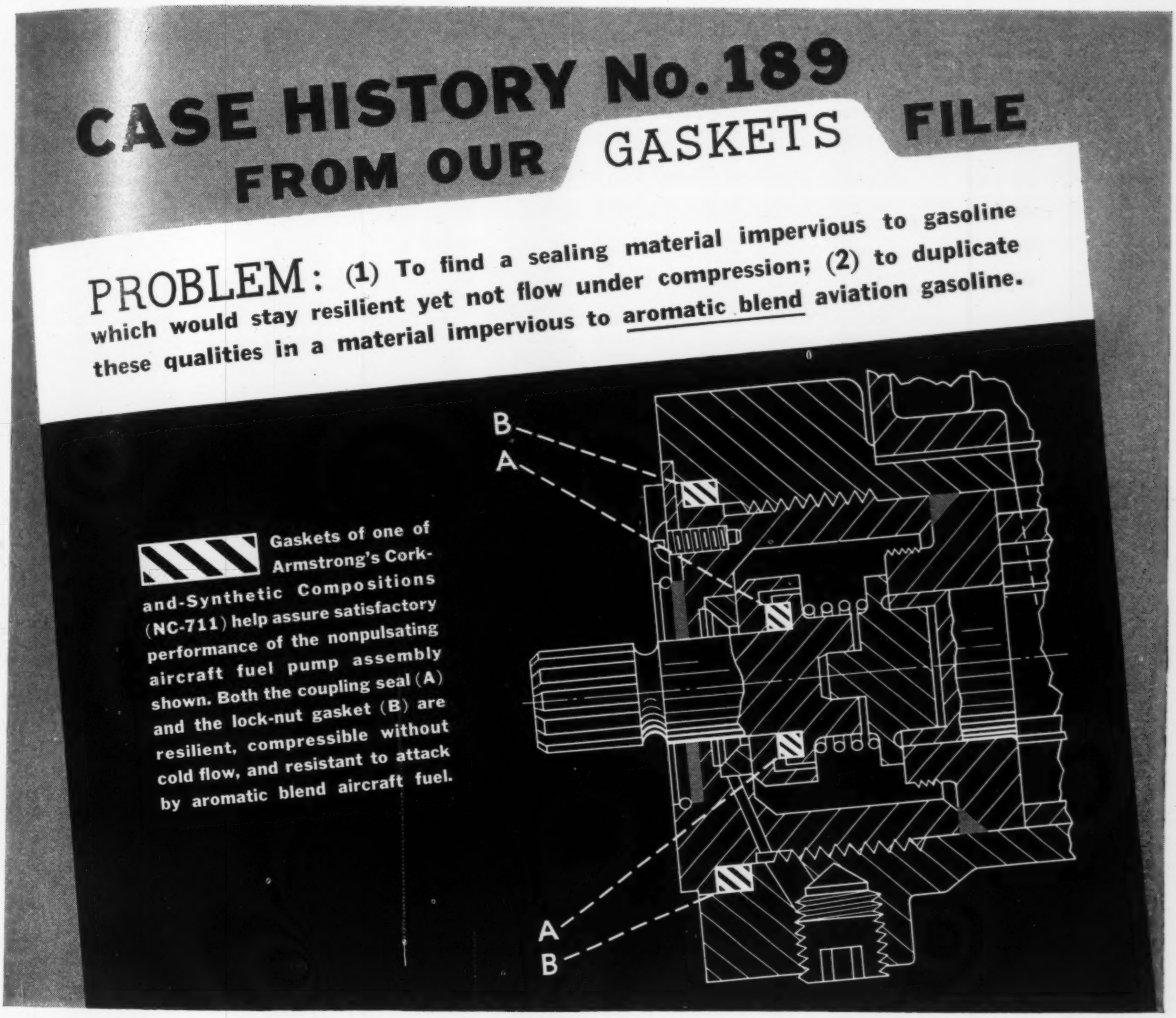


Pull-Push Button Stations

AVAILABLE on orders with priority ratings through The Arrow-Hart & Hegeman Electric Co., 103 Hawthorn street, Hartford, Conn., is a new pull-push button station for motor controls. Increased safety is an outstanding feature of these heavy-duty interchangeable units. Use is made of pull action in addition to the push, the two operations being performed with one button which cuts in half the number of buttons formerly required. Since motors are stopped and started, motions are forward and reverse, up or down, etc., this falling naturally into the layout for most control installations. A single button for stopping and starting is used—the button being pushed to stop the motor, and pulled to start. Because pushing the button can only stop the motor it "fails safe" when hit or accidentally pushed. The



CASE HISTORY No. 189 FROM OUR GASKETS FILE



PROBLEM: (1) To find a sealing material impervious to gasoline which would stay resilient yet not flow under compression; (2) to duplicate these qualities in a material impervious to aromatic blend aviation gasoline.

▧ Gaskets of one of Armstrong's Cork-and-Synthetic Compositions (NC-711) help assure satisfactory performance of the nonpulsating aircraft fuel pump assembly shown. Both the coupling seal (A) and the lock-nut gasket (B) are resilient, compressible without cold flow, and resistant to attack by aromatic blend aircraft fuel.

A WELL-KNOWN pump company had been using rubber-like rings as coupling seals and lock-nut gaskets in aircraft fuel pumps. But the sealing material was unsatisfactory because it flowed under compression. So an Armstrong cork-and-synthetic composition (DC-113) was tried and found excellent for the job. Due to its cork content, DC-113 did not cold-flow. The sealing efficiency of the synthetic in the composition was not impaired by the gasoline, and the material retained its resiliency indefinitely.

THEN CAME AROMATIC GASOLINE

The sudden advent of aromatic blend aircraft fuel created a new sealing problem. As is the case with most other sealing materials, the aromatic fuel attacked the DC-113 composition. The pump company telephoned us immediately to ask whether we could furnish a sealing material that would give the same satisfactory service with aromatic blend as DC-113 gives with regular fuel. Thanks to the variety of synthetics Armstrong uses, we were able to supply promptly a cork-and-synthetic composition (NC-711) that licked the problem.

Our files contain records of hundreds of difficult sealing problems like this . . . all solved with Armstrong's Gaskets, Seals, and Packings.

FOR YOUR SEALING NEEDS . . .

Armstrong compositions—having virtually any desired physical properties—are available in rolls, sheets, cut parts, and molded or extruded shapes. In addition to more than two dozen rubber and rubber-like compositions, the Armstrong Line includes many cork compositions . . . and No. 841 Fibrated Leather. So when *you* have a sealing problem, you can count on getting the *right* material from Armstrong Cork Company, Industrial Division, 942 Arch Street, Lancaster, Pennsylvania.

ARMSTRONG'S
GASKETS · SEALS
PACKINGS

Cork Compositions
*Cork-and-Synthetics • *Synthetics
Cork-and-Rubber • Fibrated Leather

*FORMERLY "CORPRENE"

You get exactly what you specify in

RINGS

in carbon and alloy steels

Any Size from 12" O.D. to 100" O.D.

Forged and Rolled by

TAYLOR FORGE

IF your product calls for forged or rolled steel rings it will pay you to place your requirements in the experienced hands of Taylor Forge.

As the world's largest manufacturer of forged steel flanges, Taylor Forge has amassed the finest equipment for forging, rolling, and machining rings in required carbon and alloy steels.

The comprehensive set up for heat treating and the modern laboratory and testing equipment are particularly valuable to manufacturers who want rings with specific characteristics fully verified by tests.

TAYLOR FORGE & PIPE WORKS
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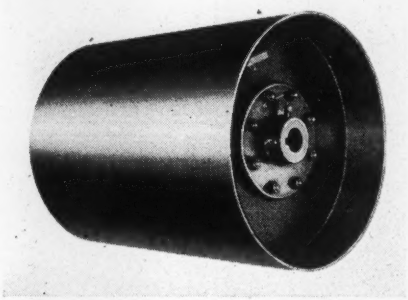
▶ Other Taylor Forge Products include: "WeldELLS" and related seamless fittings for pipe welding; forged steel flanges; forged steel nozzles and welding necks for boiler and other pressure vessel outlets; light wall spiral pipe; heavy wall electric-weld and forge welded pipe; corrugated furnaces, and similar forged and rolled products.

line of controls includes the following: In the pull-push type, momentary, 3-position (start-stop; momentary and maintained, 3-position (1-off-2); and maintained, 3-position (on-off); in the pull type, momentary (start), and in the push type, momentary (stop).

Tight-End Pulleys for Conveyors

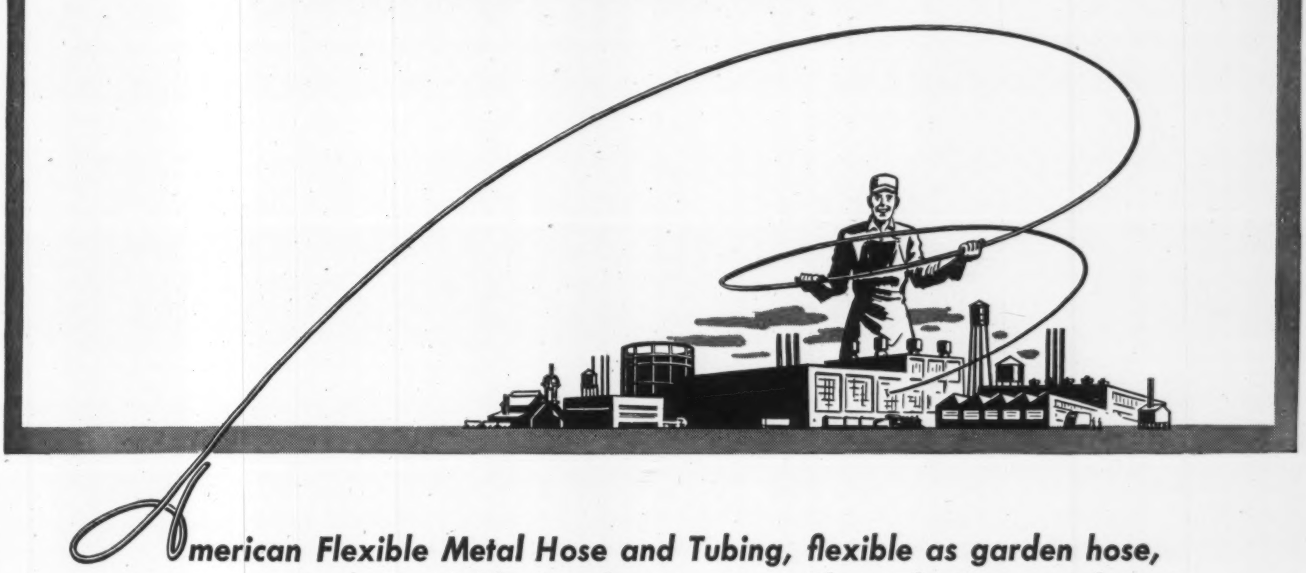
BELT conveyors can be built efficiently with the solid, tight-end conveyor pulleys recently developed by American Pulley Co., 4200 Wissahickon avenue, Philadelphia. This Type N pulley is easily kept clean. Of rolled steel and light in weight, it is practically unbreakable. Hubs are removable, interchangeable and easily mounted. Pulley diameters are 6 to 36 inches. All rims are of one-piece construction, rolled from steel and arc-welded to form a perfect one-piece cylinder. The pulleys are designed for 125 pounds effective belt tension per inch width of face, and are available in all sizes in both crown and flat face construction. If greater gripping power is needed the pulleys can be covered with vulcanized-on pulley lagging, this being a special compound vulcanized to the face of the pulley in thicknesses from 3/16 to 5/16-inch depending upon diameters.



Aircraft Cowl Fasteners

AN EFFICIENT cowl fastener in answer to the need of aircraft manufacturers for a quicker, more secure and trouble-free method of attaching cowling and other removable parts is being offered by the Aviation division of Shakeproof Inc., 2501 North Keeler avenue, Chicago. Consisting of three parts, main spring, stud and cross pin, the fastener can be installed by riveting the main spring in place over a drilled or punched clearance hole in the inner surface sheet. The stud member is inserted in a matching clearance hole in the outer sheet and the cross pin press-fitted in the stud. Upon closure of cowling or removable part, stud member and main spring quickly come into alignment position. A clockwise quarter-turn locks stud and pulls parts together with a powerful dual spring tension. Conforming to proposed Army and Navy Specifications and having passed official Air Force Tests, the cowl fasteners reinforce adjacent structural area, present no stress hazards, provide limited deflection with high initial axial tension, compensate for usual variation in com-

Sinews of metal to fight Industries' Battles...



American Flexible Metal Hose and Tubing, flexible as garden hose, strong as rigid pipe, keeps pace with production speed-ups

THE Machine Tool Industry has never been busier, never been more vital to our country's welfare than it is today. The development of our war program, our future in peacetime—both are highly dependent upon the efficient, uninterrupted operation of this industry.

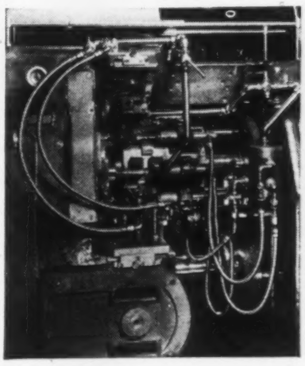
To the Machine Tool Industry the name "AMERICAN" has a great significance; it carries with it the assurance that the product will be dependable. Whether for coolant, drain or hydraulic lines, the flexible connectors on machine tools must have this dependability, for downtime is costly.

• • •

Add to this long life, ease of installation, and adaptability to design, and you have the reason why the industry on which America depends, depends on "AMERICAN"!

Today, the war program demands most of our production, and will probably continue to do so until victory is assured.

42185



Machine Tools Stay Cool with American Flexible Metal Oil Feed and Coolant Tubing—as on this multiple spindle automatic bar machine, where it accurately directs the flow of coolant to the several metal parts being worked simultaneously.

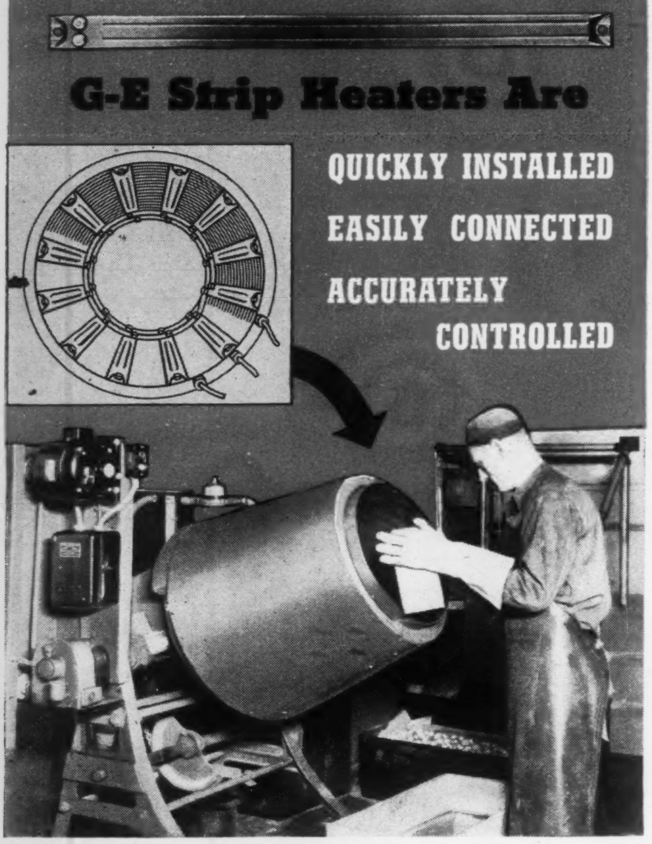
American "SEAMLESS", at top... no seams, no welds, no joints, no packing . . . as pressure-tight as the metal tube from which it is made. Lower, American "INTERLOCKED", for use where only the most rugged type of steam or oil hose can be tolerated—full interlocked joints are packed with asbestos to insure tightness when used under pressure.

ANACONDA
from mine to consumer

American Metal Hose

AMERICAN METAL HOSE BRANCH OF THE AMERICAN BRASS COMPANY • GENERAL OFFICES: WATERBURY, CONN.
Subsidiary of Anaconda Copper Mining Company • *In Canada:* ANACONDA AMERICAN BRASS LTD., *New Toronto, Ontario*

Need Electric Heat In Rotating Machinery?



BUILDING heat into a rotating machine was a problem faced by the manufacturer of Lasalco Letric tumblers. The heat had to be accurately controlled. G-E strip heaters were installed.

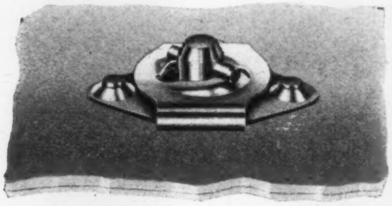
These electric heaters were connected to the power supply through two slip rings mounted under the tumbler barrel. Installation was quick and easy. Exact temperature control, by means of a thermostat, is simple.

These porcelain-enameled, steel-sheathed heaters are recommended for scorchers, drying cabinets, and process machinery where surface heat is needed. They are constructed to withstand vibration and provide even heat distribution. Lengths, 7 to 35 inches; ratings up to 1500 watts; sheath temperatures up to 1200 F.

If you have a process machine needing heat that falls within these specifications of G-E strip heaters, submit details to our nearest office. Our engineers will figure out your specific requirements. For more information on strip heaters or other midget heaters and devices, get our catalog, GED-650B. *General Electric Co., Schenectady, N. Y.*

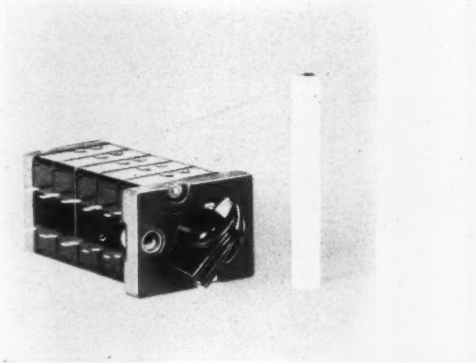
GENERAL ELECTRIC
675-42-8709

mercial aluminum sheet thickness, and will not bind when used on curved surfaces. They are available in two sizes to conform to AN strength classifications 5 and 7 (up to 500 and 700 pounds tension respectively), and with flush, oval and wing head studs. Standard units can accommodate total material thicknesses ranging from .035 to .254.



Aircraft Multicircuit Switch

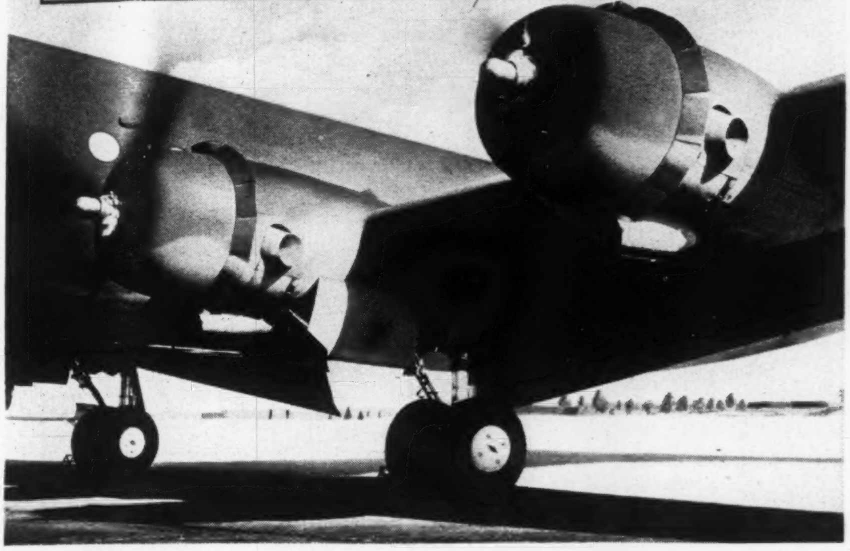
ANNOUNCED by General Electric Co., Schenectady, is a multicircuit switch which opens, closes or transfers as many as twenty circuits simultaneously by means of a two-position operating knob. Contact mechanisms are switchettes stacked in pairs. The switchette is snap action, double-break in construction, giving it a high current rating. Available with from eight to twenty switchettes, and in either single-circuit or two-circuit form, the new switch meets specifications set up by the U. S. Army Air Forces for devices of this type used in aircraft service. A shaft toggle switch insures positive switch position. Weight varies from 5 1/3 ounces to 10 2/3 ounces depending upon the size selected.



Coolant Pumps Flange Mounted

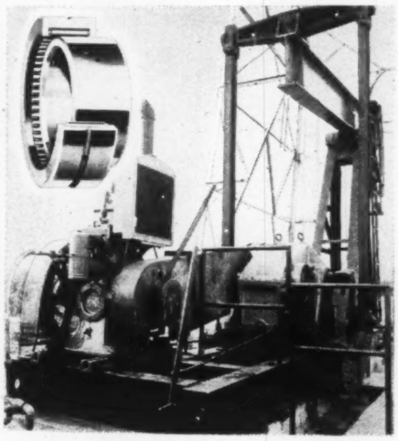
STURDILY-BUILT flange-mounted coolant pumps announced by Gilbert & Barker Mfg. Co., West Springfield, Mass., are applicable to milling machines, turret lathes and other machine tools. The one-quarter horsepower motor, with terminal box built into the end bell, is totally enclosed and designed for continuous operation without overheating. Any possibility of liquid reaching motor is prevented by a positive mechanical seal ring on the motor shaft. Statically and dynamically balanced, an open-type bronze impeller

IN THE NEWS WITH BANTAM BEARINGS



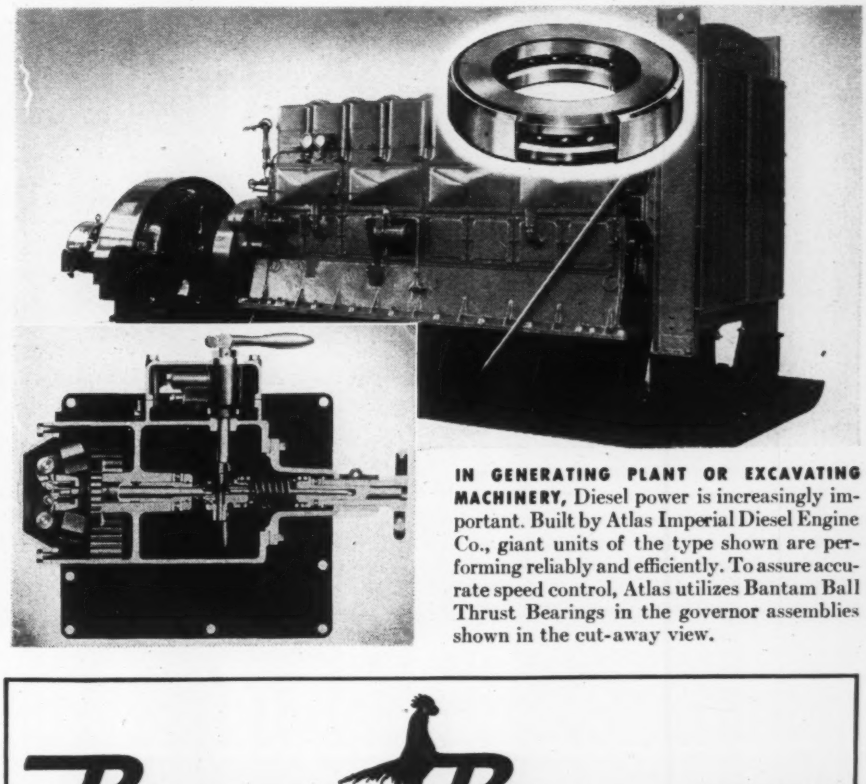
GIANT ENGINES KEEP THEM FLYING, furnishing smooth, unfailing power for America's fast-expanding air fleets. Many of the nation's speediest, most efficient bombers, fighters, transports, and cargo planes are powered by huge, air-cooled, radial engines that develop 2,000 horsepower. Among the many engineering features that contribute to the successful performance of these engines is the use of Bantam Needle Rollers to provide anti-friction bearing units of unusually light weight and small size in proportion to their load capacity.

WELL DRILLING SPEEDS ARE FASTER, loads are heavier, depths are greater. 8-inch Oil-bath Rotary Swivels built by The International Derrick and Equipment Company embody in their design every feature and strength factor necessary in present-day drilling practice. Bantam Bearings provide a safe load capacity far above the most rigid requirements of the service, are a vital factor in the high performance standards of the equipment.



BACKBONE OF A COMBUSTION ENGINE is the crankshaft construction—and Weber Engine Company, after exhaustive studies, selected Bantam Quill Bearings for use on this vital part of their Vertical Gas Engines. Bantam Quill Bearings combine the advantages of anti-friction construction, high load capacity, small size, and ease of installation. For full details on this unusual bearing, write for Bulletin B-104.

BANTAM'S ENGINEERING COOPERATION is especially valuable in meeting new and unusual requirements. Bantam makes every major type of anti-friction bearing—straight roller, tapered roller, needle, and ball. Bantam engineers aid in the selection of the type that best suits your application—or design special bearings that meet your requirements. If you have a difficult bearing problem, TURN TO BANTAM.

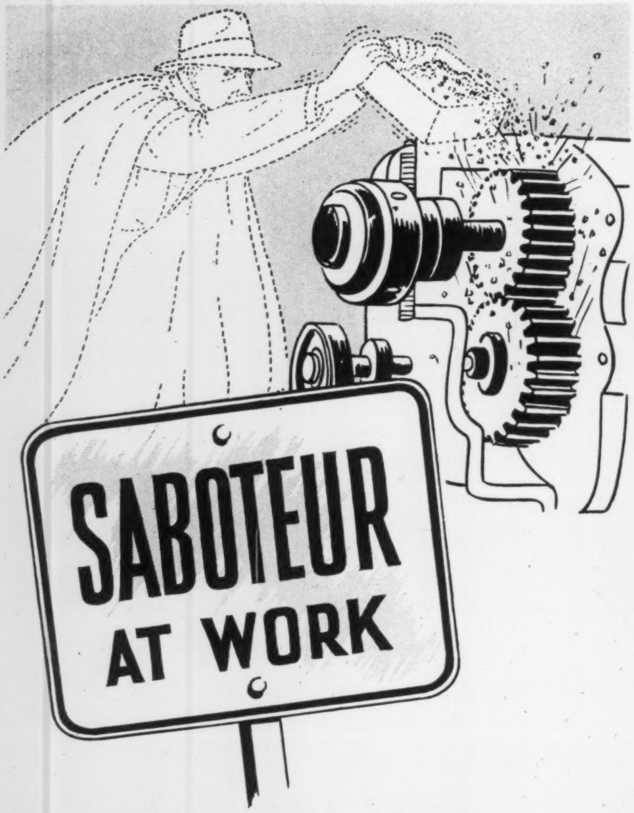


IN GENERATING PLANT OR EXCAVATING MACHINERY, Diesel power is increasingly important. Built by Atlas Imperial Diesel Engine Co., giant units of the type shown are performing reliably and efficiently. To assure accurate speed control, Atlas utilizes Bantam Ball Thrust Bearings in the governor assemblies shown in the cut-away view.

BANTAM BEARINGS

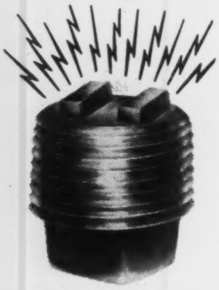
STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

BANTAM BEARINGS CORPORATION • SOUTH BEND • INDIANA

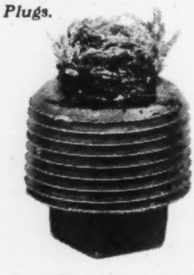


You can't see this saboteur — but he's there just the same . . . *grinding down the life of your product!*

In all mechanical equipment, the contact of one moving part against another results in the continuous formation of metal cuttings and chips. These razor-sharp particles act as abrasives in the lubricant and result in excessive wear unless promptly removed.



● *Abrasive iron and steel particles are easily removed from the lubricant with Magnetic Drain Plugs. No change in production or assembly necessary. Simply replace ordinary plugs with Magnetic Plugs.*



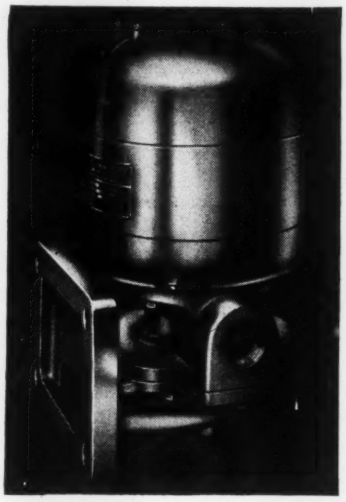
● *The powerful, permanent magnet catches and holds the abrasive metal, stops excessive wear and thus prolongs the life of the equipment.*

FOR present war-time production, or for future peacetime products, Magnetic Plugs offer practical protection against excessive wear. Write for interesting details on applications.

LISLE CORPORATION • Box 1003 • Clarinda, Iowa

Magnetic
DRAIN PLUGS

is secured to lower end of motor shaft with a key and locking nut. Pump is furnished as standard with outlet on left side when facing machine, but is also available with outlet on right side. Self-priming, this Model CF pump delivers coolant immediately and will handle liquids charged with filings and chips as large as thirty-five thousandths without stoppage. Construction of pump prevents any trapping of air, and also permits it to run dry without harm. Capacity of the pumps ranges from a fraction of a gallon to approximately 17 gallons per minute free flow, and any commercial coolant can be used. Flow can be retarded without use of relief or by-pass valves. Pumps are furnished in machine tool gray finish.

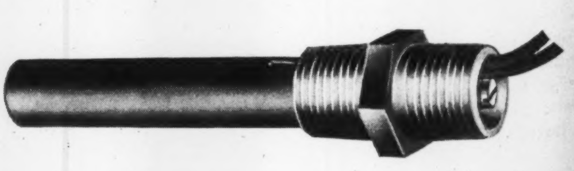


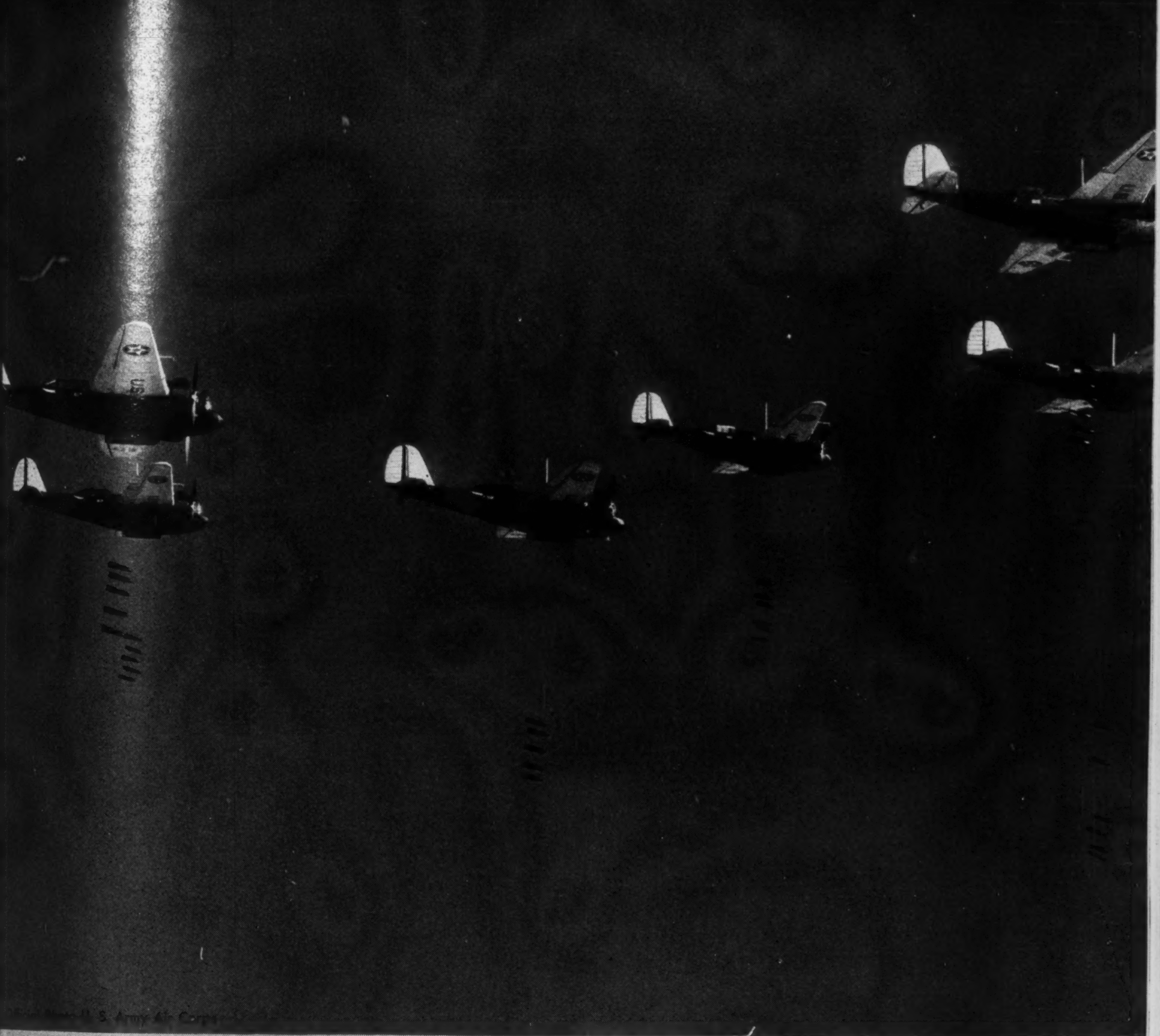
Small Aircraft Electric Motor

WOUND for 1/13 horsepower at 8500 revolutions per minute a new type small electric motor for aircraft is offered by Signal Electric Mfg. Co., Menominee, Mich. It is available for either 12 volts or 24 volts, for aerial antennae reels. Diameter of housing of type LD3R is 2.306 inches; overall length, not including the shaft extension, 2$\frac{13}{16}$ inches; weight 1 pound, 3 ounces; shaft extension .766-inch; and shaft diameter, .250-inch. The motor is equipped with ball bearings, and is reversible (3 leads).

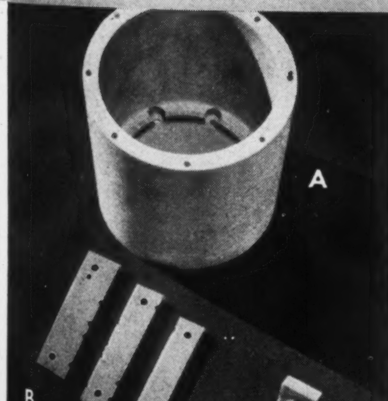
Coupling Head Thermoswitch

DEVELOPED by Fenwal Inc., Ashland, Mass., a new coupling head thermoswitch is similar to the regular "Hex" type designed for insertion into closed liquid or gas systems by means of a ½-inch standard pipe thread. The new coupling head facilitates permanent wiring connection quickly and neatly. Another important feature of the thermoswitch is the ease with




Official Photo U. S. Army Air Corps

Tokio, Nagoya, Osaka, and Points East



A—Detector Case, turned, threaded, bored, drilled, tapped and counter-bored.

B—Sawed and drilled insulators.

C—Filter bracket, sawed, milled and drilled.

WHERE did those planes come from? Where did they go? We don't know. All we do know is that they got there—and that mighty armadas will follow them.

Synthane, because of its combination of properties, is valued in wartime production. These properties include excellent electrical insulating characteristics, light weight (half the weight of aluminum), structural strength, ease of machining, and resistance to corrosion from solvents, petroleum products, water, many acids and salts.

If you are producing to win this war, and are not as familiar with laminated plastics as you'd like to be, let us help. We have a number of folders—ready now—on: 1. Synthane Sheets, 2. Synthane Tubing, 3. Technical Plastics for Industry, 4. Synthane Gear Material, 5. Corrosion-Resisting Synthane, 6. Practical Methods for Machining Bakelite-laminated Plastics, 7. The Synthane Sample Book, containing Synthane grades.

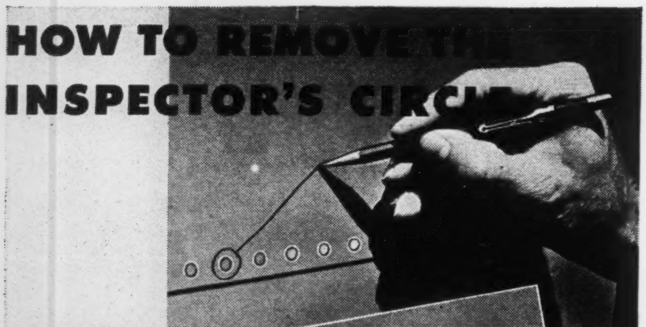
SYNTHANE CORPORATION, OAKS, PENNA.

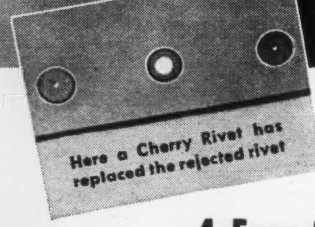
Plan your present and future with plastics

SYNTHANE TECHNICAL PLASTICS

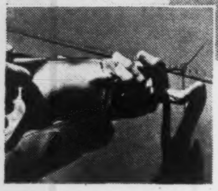
SHEETS • RODS • TUBES • FABRICATED PARTS | **SYNTHANE** *Bakelite—laminated* | **SILENT STABILIZED GEAR MATERIAL**

HOW TO REMOVE THE INSPECTOR'S CIRCLE

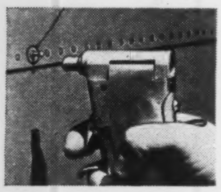




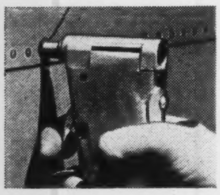
Here a Cherry Rivet has replaced the rejected rivet



1 Remove the rejected rivet in the normal way by drilling.



2 Insert the next size larger Cherry Blind Rivet. This may be done by placing the rivet in the hole first, as shown here, or by placing the rivet in the gun head.



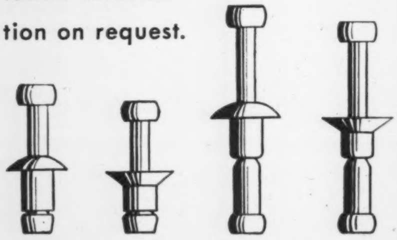
3 With gun in position, depress the trigger. The heading operation is completed instantly. Projecting mandril breaks, releasing gun.

4 Flat-ground nippers remove the remaining portion of the pulling mandril. The job is finished in less time than it takes to show you these steps.

4 Easy Steps with Cherry Blind Rivets

The inspector's circle, indicating a rejected rivet, can be a very expensive mark unless you replace with Cherry Blind Rivets. This rivet eliminates the time-consuming and costly step of removing inner skin to gain access to the blind side because it heads itself on the blind side.

The Cherry Rivet is applied with a special gun which pulls on the mandril and pushes on the rivet head forming a tulip head on the blind side, expanding the shank and permanently plugging the rivet. This positive mechanical action assures the formation of a satisfactory head on the blind side. Detailed information on request.



From left to right, the hollow type with brazier and countersunk heads — the self-plugging type with both styles of heads. All are applied with either the hand or power gun.

MANUFACTURED UNDER U. S. PATENT NUMBER 2,183,543 AND OTHER PATENTS PENDING

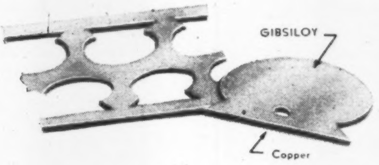
PHOTOS COURTESY ANDERSON AIRPLANE SCHOOL

Cherry Rivet Company
LOS ANGELES, CALIFORNIA
© 1942 C. R. C.

which many types of condulets may be attached to its head, such as waterproof or explosionproof fittings. Hex-head thermoswitches are referred to as regular (A) when contacts open on an increase in temperature; inverse (I) when contacts open on a decrease in temperature. Adjustable operating range is 50 to 400 degrees Fahr. Contact rating is 10 amperes, 115 volts; 5 amperes, 230 volts, alternating current. The switch can also be furnished up to 600 degrees Fahr., if desired.

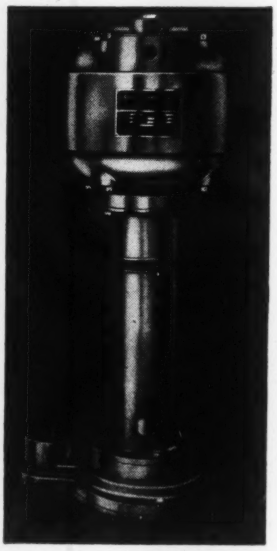
Laminated Metal Contacts

CONTACTS of Gibsiloy are being made available by Gibson Electric Co., Pittsburgh, in laminated metals in which Gibsiloy materials and base metals are combined to obtain best features of each. Because of its electrical properties, Gibsiloy is used as a facing on the contact surfaces and inexpensive base metals are used for backing material. These contacts are produced by special processing of metal powders which do not naturally alloy with one another. Available in both inlay and overlay types, with Gibsiloy or fine silver or other precious metal contact surfaces, the contacts are suitable for a wide variety of contact applications.



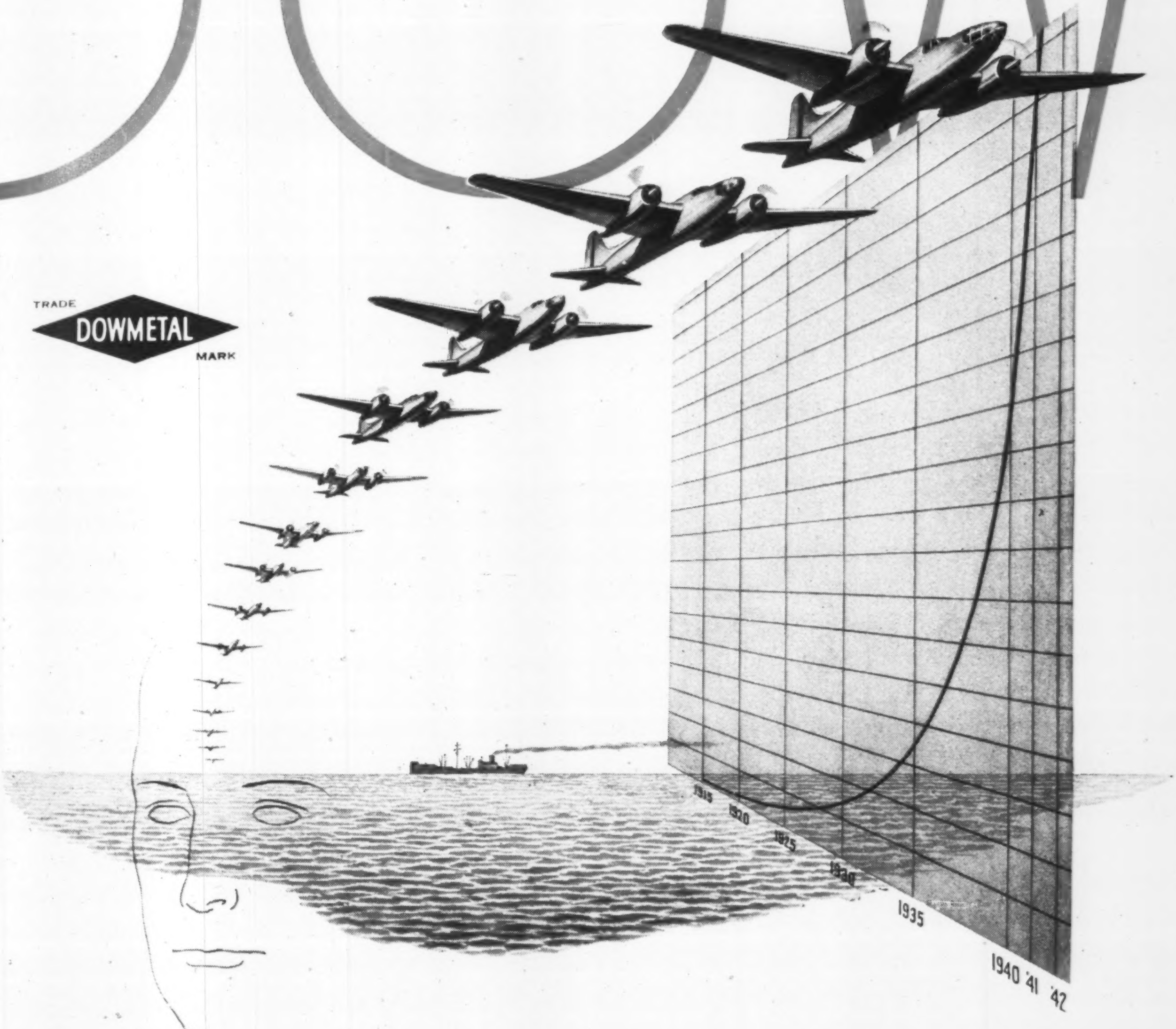
Immersion Coolant Pumps

RECOMMENDED for handling any coolant which may become contaminated with abrasives, Model CE centrifugal pumps introduced by Gilbert & Barker Mfg. Co., West Springfield, Mass., are manufactured with three different heights of pedestals for sump or tank mounting. Motor, pump and terminal box are a compast, integral unit, with the motor of one-quarter horsepower, totally enclosed, and designed for continuous operation without overheating. Terminal box is built into the motor end bell. Secured by a locking nut to the lower end of the rigid shaft is an open-type bronze impeller, statically and dynamically balanced. Because of this type of impeller, the pumps will pass abrasive impurities as large as thirty-five thousandths in diameter without stoppage or dam-



DOW

TRADE **DOWMETAL** MARK



CONSTRUCTION of airplanes for victory calls for a boundless supply of magnesium. The production curve of this remarkable weight-saving metal rises ever higher as Dow extracts millions of pounds from the waters of the sea. The eye of the designer is on the future when these vast quantities of magnesium will release more horsepower for peaceful purposes and lighten our daily tasks in innumerable ways.

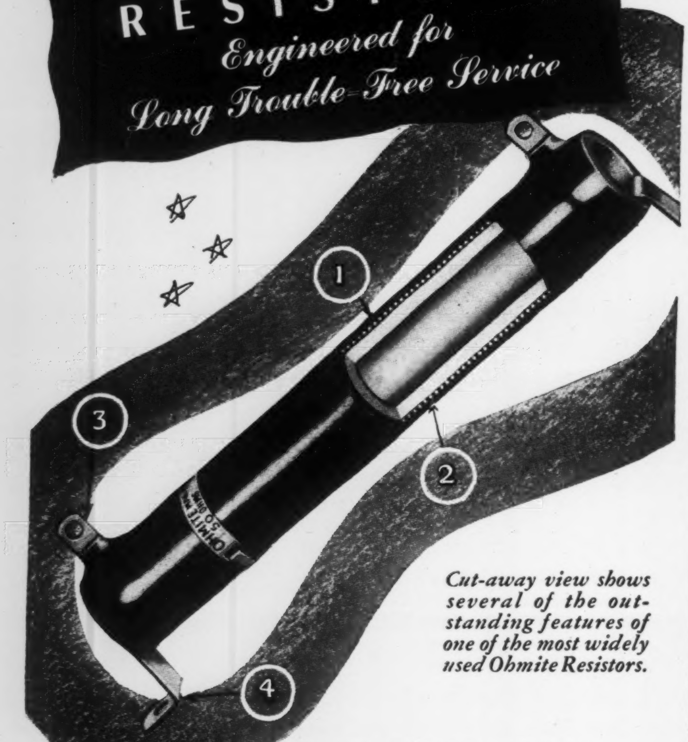
THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN

DOW MAGNESIUM

MAGNESIUM

The Lightest Structural Metal . . . One-third Lighter Than Any Other in Common Use

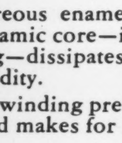
OHMITE
RESISTORS
Engineered for Long Trouble-Free Service



Cut-away view shows several of the outstanding features of one of the most widely used Ohmite Resistors.

1. Ohmite vitreous enamel holds the wire in place on ceramic core—insulates and protects the winding—dissipates heat rapidly—withstands humidity.
2. Evenness of winding prevents "hot spots" and failures—and makes for long, reliable service on the job.
3. Resistance wire both mechanically locked and brazed to copper terminal lugs, assuring perfect electrical connection between lugs and wire.
4. Mounting brackets hold resistor firmly yet resiliently in place. Easy to mount—easy to remove.

More than sixty different core sizes make possible an almost endless variety of regular or special resistors to meet every need. Ohmite Engineers are glad to help you on any resistor problems in connection with Governmental or Industrial requirements.



Write on company letterhead for complete, helpful 96-page Catalog and Engineering Manual No. 40.

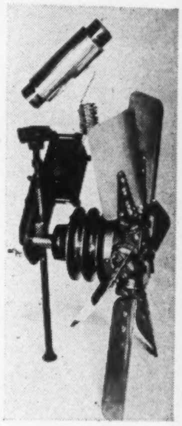
OHMITE MANUFACTURING CO.
4332 Flournoy Street, Chicago, U.S.A.

BE RIGHT WITH ★ OHMITE
Rheostats·Resistors
Tap Switches

age. Coolant enters the pump through four inlet ports in pedestal, flows downward to impeller chamber and is passed through volutes to the vertical pipe-threaded outlet. Self-priming, the pump never becomes air-bound and delivers coolant immediately. Capacities of the units range from a fraction of a gallon to approximately 21 gallons per minute free flow. No by-pass or valve is needed for retarded rates of flow.

Variable Pitch Fan Produced

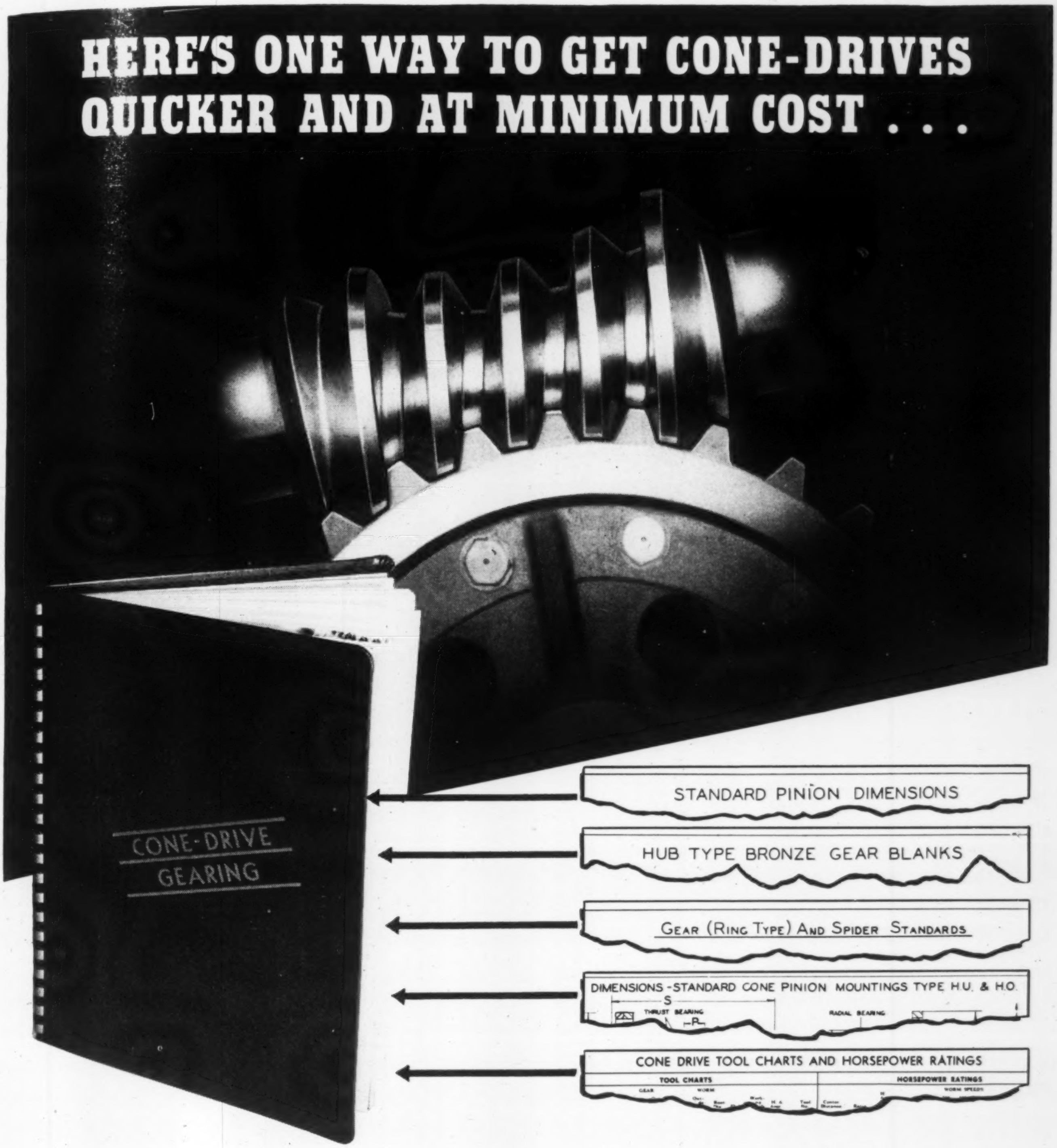
FOR accurate control of cooling water temperature for gasoline or diesel engines primarily, Kontrol-Fan Inc., Los Angeles, has developed a variable pitch fan which automatically draws more or less air through engine radiator based on amount of air required to maintain predetermined temperature. Entirely automatic in operation, fan blade assemblies function in a similar manner to the variable-pitch propellers that are standard on all military aircraft in that blades feather from practically zero pitch up to as much as 38 degrees pitch. A thermostat tube is placed between water outlet on cylinder head and top of radiator, using part of existing hose connection. In accordance with temperature of cooling water, sylphon bellows expand or contract, and through a simple lever arrangement actuate the fan blade angle between minimum and maximum pitch. A predetermined temperature can thus be maintained.



Heavy-Duty Industrial Caster

HEAVY-DUTY caster requirements have brought about a new industrial caster designed by The Rapid-Standards Co., Grand Rapids, Mich. The company is now producing a series of 8 and 10-inch casters with a minimum of wearing parts and embodying structural features especially adaptable to materials-handling problems found in aviation and other war production plants. Steel forgings are used in the top plate and swivel head of the new caster, while legs, or forks, are heavy bar stock securely welded to swivel head. The shape of the fork and the method of designing it are new features of the caster that more than double the strength. The new caster is capable of withstanding shocks and striking

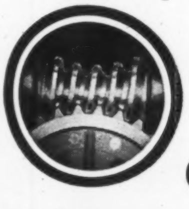
HERE'S ONE WAY TO GET CONE-DRIVES QUICKER AND AT MINIMUM COST . . .


CONE-DRIVE GEARING
STANDARD PINION DIMENSIONS
HUB TYPE BRONZE GEAR BLANKS
GEAR (RING TYPE) AND SPIDER STANDARDS
DIMENSIONS - STANDARD CONE PINION MOUNTINGS TYPE H.U. & H.O.
CONE DRIVE TOOL CHARTS AND HORSEPOWER RATINGS

Whether our need tomorrow will be for improved designs of equipment to win the war, or whether it will be for new industrial products to win the peace, here is a simple way in which you will be able to help yourself save time and money:

Design your products to take STANDARD Cone-Drives.

A great many of today's Cone-Drive gear applications require specialized tooling and the casting, forging, and machining of special blanks. One reason is that higher capacity, lighter weight per horsepower, longer lived Cone-Drives have had to be fitted into designs frequently intended for other forms of reduction gearing.

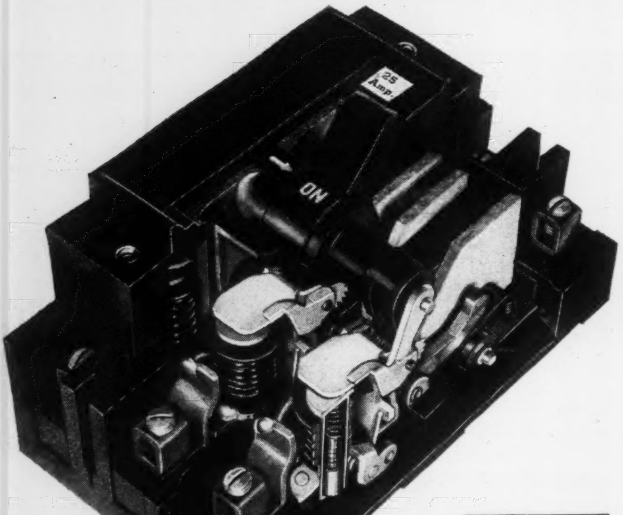


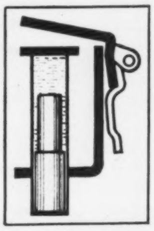
Another is that the design of the gearing has been left until after other controlling dimensions of the equipment have been established. Whatever the reason, time is lost and money spent in preparing to produce the actual gearing.

We will be glad to supply you with specifications of STANDARD Cone-Drive designs including tables of already available tooling for hundreds of ratios and sizes.

CONE-DRIVE DIVISION MICHIGAN TOOL COMPANY
7171 E. McNichols • Detroit, U.S.A.

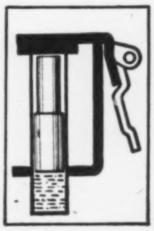
"Inside" Dope ..... on
HEINEMANN
MAGNETIC
CIRCUIT BREAKERS




Plunger in normal position at bottom of cylinder.

TIME DELAY ON OVERLOADS

The magnet coil surrounds a hermetically sealed and liquid filled cylinder containing an iron core. This plunger, normally out of the magnetic field, moves into the field on overloads with the liquid controlling the speed of the plunger. The magnetic flux increases as the plunger rises attaining its maximum when the plunger reaches the top. At this point the trip armature is attracted to the pole piece and operates the latch mechanism, opening the contacts. Various time delays can be had by the use of liquids of different viscosities.


Plunger after overload with armature attracted to pole piece, opening contacts.

INSTANTANEOUS ACTION ON SHORT CIRCUITS

Short circuit currents energize the pole piece with sufficient speed to attract the armature before the plunger moves.

BLOWOUT ACTION AT CONTACTS

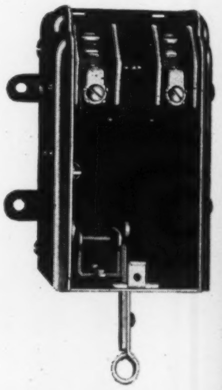
Magnetic blowout contacts mounted in individual arcing chambers speed up the arc interruption. As the value of the current increases the quenching effect becomes greater due to the intensified magnetic blowout field.

Send for Catalog 40 showing complete line

HEINEMANN CIRCUIT BREAKER CO.
Subsidiary of Heinemann Electric Co.
Est. 1888
113 PLUM STREET TRENTON, N. J.

of obstructions without impairing its efficiency and workability. It is equipped with a resinoid all-purpose wheel, or can be furnished with Nicro-steel wheels. Soft or hard tread rubber wheels can also be furnished for WPB approved applications.

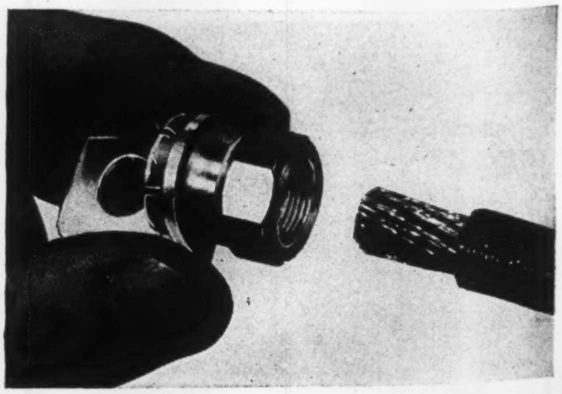
Liquid-Level Float Controls



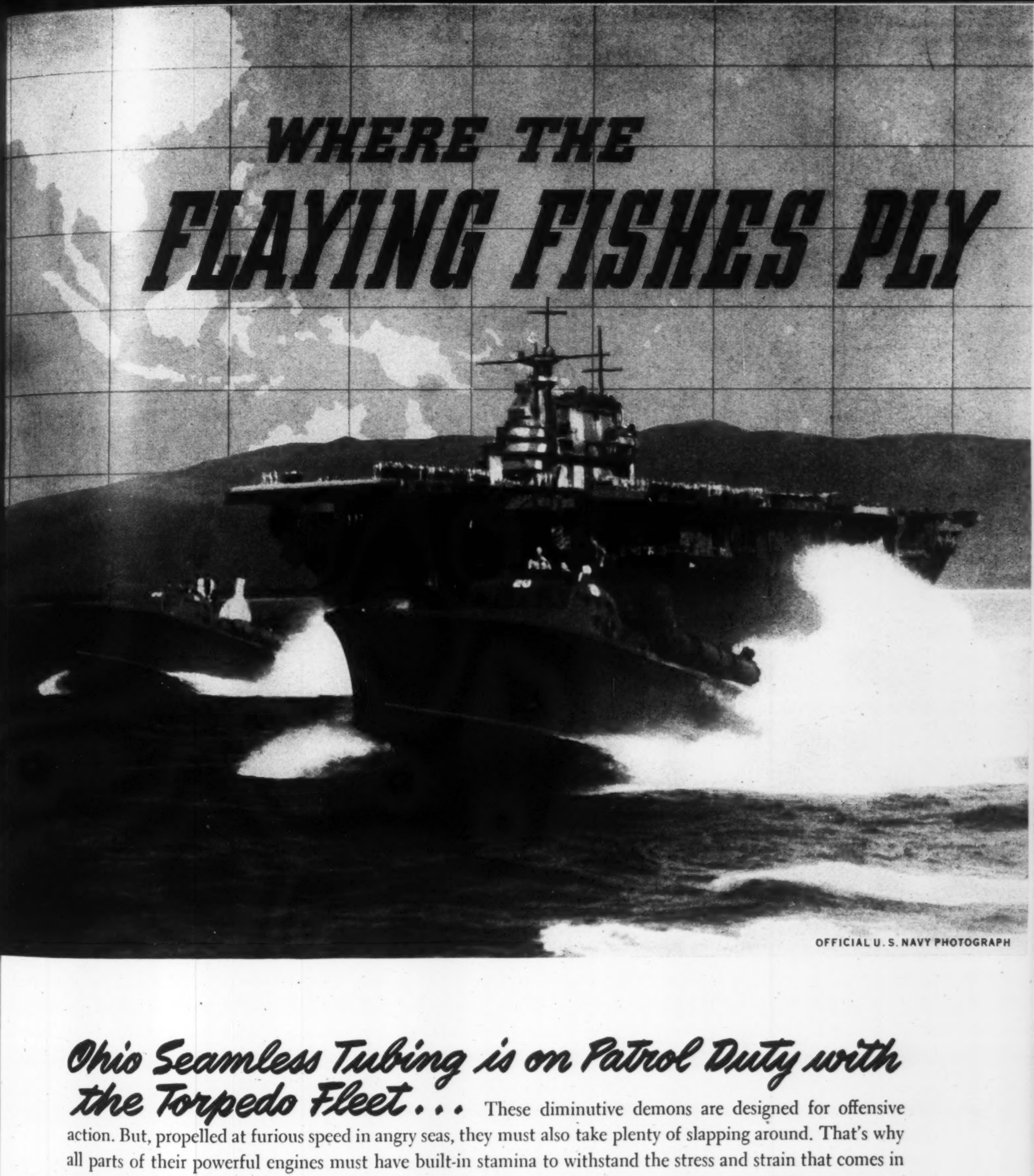
FOR starting and stopping electric motors by changes in liquid level, two new series of float controls have recently been announced by Penn Electric Switch Co., Goshen, Ind. In the 152 series two-pole construction is available, while in the 110 series, single, double or three-pole construction can be obtained. The controls in either series can be reversed easily from open tank to sump operation (or vice versa) by simply changing the pivot location of the operating arm lever. Heavy-duty, double-break contact structure actuated by the company's "V-overroller" trip mechanism assures positive snap-action on make and break. Electrolytic silver contacts are completely accessible without dismantling any part of the control, and are mounted in deep-channeled plastic blocks. A close-fitting cover can be removed easily for wiring, etc.

Cable Lug for Aircraft Use

BECAUSE an incorrect cut was used to illustrate the announcement covering a new cable lug for aircraft in the July issue, the correct cut is reproduced below and the primary facts relating to these cable lugs restated. Suitable for aircraft, marine and commercial applications, Aircraft-Marine Products Inc., Elizabeth, N. J., has developed a new lightweight cable lug for wire sizes No. 2, No. 0 and No. 00. A collet type clamping ring when compressed by a tightening nut applies uniform pressure from all directions, insuring perfect electrical contact. Easy inspection of contact is permitted as wire end is always visible. When tightening nut is released the collet ring expands, permitting wire to be



WHERE THE FLAYING FISHES PLY



OFFICIAL U. S. NAVY PHOTOGRAPH

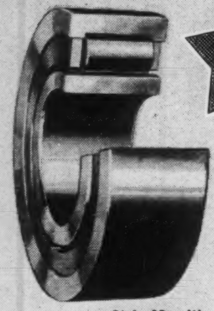
Ohio Seamless Tubing is on Patrol Duty with the Torpedo Fleet . . . These diminutive demons are designed for offensive action. But, propelled at furious speed in angry seas, they must also take plenty of slapping around. That's why all parts of their powerful engines must have built-in stamina to withstand the stress and strain that comes in the line of duty. ¶ In at least five vital spots Ohio Seamless Tubing takes over this responsibility in many of the marine motors that power torpedo patrol boats. For camshaft rocker lever shafts, water tubes, oil line, gas lines, bearing and bushings — for all these engine parts Ohio Seamless supplies tubing to meet the Navy's exacting specifications. ¶ On both production line and firing line this tubing has proved its mettle for machinability, hardness, and accuracy as to size and gauge. And just as its quality, precision-workmanship, uniformity and strength now add to the superiority of America's hard-hitting weapons for Victory, so will they help give you a competitive advantage when you again manufacture products for peacetime.

THE OHIO SHELBY, OHIO **SEAMLESS TUBE COMPANY**

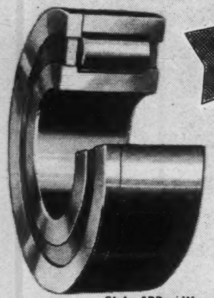
OHIO SPECIAL QUALITY

Completely Right for Radial Loads!

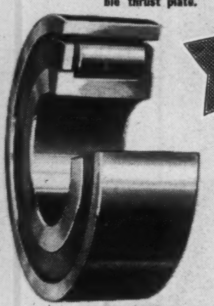
Now you can have the superior performance of AMERICAN RADIAL ROLLER BEARINGS for almost every heavy-duty bearing application where the load is radial. Through popular demand for a wider range of these adaptable, reliable, durable bearings, AMERICAN has extended its RADIAL line to include 5 styles, 4 S.A.E. series and a total of 85 sizes! Supplementing these, special designs to order are also available. AMERICAN thus becomes a single dependable source for a COMPLETE line of Radial Bearings. Each is a leader in its class . . . designed to meet exacting engineering requirements and to function flawlessly in service under the most rigorous conditions. Write for specifications or send us your requirements for analysis and recommendations.



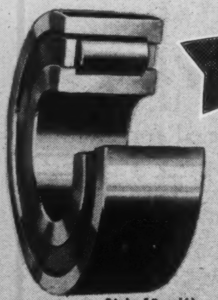
Style AD, with grooved outer race; straight inner race.



Style ADD, with grooved inner race; 1 lipped outer race; removable thrust plate.



Style AM, with grooved inner race; straight outer race.



Style AC, with grooved inner race; 1 lipped outer race.

AMERICAN ROLLER BEARING CO.
PITTSBURGH
PENNSYLVANIA

HEAVY DUTY

Pacific Coast Office
1718 S. Flower Street
Los Angeles, Calif.

AMERICAN
HEAVY-DUTY
ROLLER BEARINGS

easily removed. Three simple parts comprise the lug which is made of copper for highest conductivity and is hot electrotinned for corrosion resistance.

General-Purpose Plastic

ADAPTABLE to many uses through a minor revision in its formula, Durez 11540, a general-purpose phenolic molding compound produced by Durez Plastics & Chemicals Inc., North Tonawanda, N. Y., has already been adopted for several war production parts requiring military approval. This material has slightly higher impact strength and greater water resistance than the former top-grade general-purpose materials. An excellent surface finish can be obtained. Equipment such as field communication equipment, instrument cases, housings, and parts which must withstand hard usage is now being molded of this material.

Engineering Dept. Equipment

Photoelectric Protection Unit

TYPE A28L photoelectric intrusion protective system, developed by Photoswitch Inc., 21 Chestnut street, Cambridge, Mass., is claimed to project practically invisible light beam for distances of 350 to 700 feet, making possible the complete surrounding of power plants, war factories and other vital areas. If beam is broken by intruders, photoelectric control contacts are closed, thereby actuating flood lights, bells, gates or whatever electrical devices may be wired into the circuit. It is unaffected by changes in local light and can operate 24 hours a day. Relay contacts are pure silver and will handle 15 amperes alternating current and 8 amperes direct current. Control operates from 115 volts alternating current.

Drawing Instruments Offered

RECENTLY announced by V & E Engineering Co., Pasadena, Calif., are drawing instruments available in three combinations of bows, drop bows

Announcing the New MODEL 7500 COOLANT PUMPS

PATENT APPLIED FOR

Designed by Francis E. Brady, Jr., Hydraulic Engineer. Consultant to many machine tool manufacturers.

The most adaptable pump of all . . . MODEL 7500 by BRADY-PENROD, INC.! This pump may be made an integral part of any grinder, lathe, cutting or drilling machine or can be easily moved from job to job as needed. A plate adapter is available to fit any tank or base opening. This model is a motor-driven open-impeller centrifugal type, submergable, with an outside discharge. Internal piping is eliminated; external piping reduced to a minimum. This simplification saves engineering and assembly labor.

THREE DEPTHS SUITABLE FOR ALL MACHINES

MODEL 7500 is available with 3 different depths from flange - 4⅞", 9", and 15".

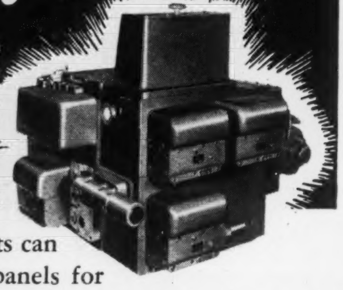
Motor capacity - ⅛ H.P. to 1½ H.P.

Controlled flow - from 4 g.p.m. to 100 g.p.m. with any standard coolant fluid. Suitable for use with abrasives. Special depths available.

Long used as standard equipment by machine tool manufacturers, BRADY-PENROD Pumps (6 other models) are proving their reliability and high hydraulic efficiency in hundreds of locations today. Write or wire for details.

Brady-Penrod
INCORPORATED
1212 W. SECOND STREET
MUNCIE, INDIANA, U. S. A.

DESIGN YOUR HYDRAULIC MACHINES WITH THESE COMPLETE CIRCUITS



Complete hydraulic circuits can be furnished as units or panels for Milling, Boring, Grinding, Drilling and other metal working machines. No Hydraulic knowledge is necessary to obtain a superior hydraulic machine. You merely establish the functions of the machine to be done hydraulically; our engineers will design the proper circuit and unit while you design the machine.

Use Only ONE Hydraulic Unit For Any Combination of:

Feed and Traverse for multiple or single tools—any type—any number of stations. Feed and traverse units can be horizontal, vertical, angular or in any combination of different positions.

Clamping of work piece in fixture with direct or indirect pressure—single or multiple stations.

Indexing or work transferring on trunnion type fixtures or horizontal indexing . . . also hydraulic actuation to index pin location.

TWO TYPES OF UNITS AVAILABLE

A Barnes self-contained hydraulic unit, as shown above, is furnished with necessary pumps and valves to complete the hydraulic functions of your machine. Hydraulic oil reservoir is included. Providing cylinder space in your machine design and connecting two pipes to each cylinder constitutes your total hydraulic effort. A Barnes Panel Unit is similar to the self-contained unit except provision must be made in the machine for oil reservoir. For complete information write for the booklet offered below.

FREE New Data: Included in this 40 page book are typical installation circuits, complete data covering piston and gear pumps and complete information covering basic elements of construction and installation of standard units used in these highly successful hydraulic circuits. Write for your copy today. Ask for Bulletin MD942.

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hydraulics
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John S. Barnes Corporation

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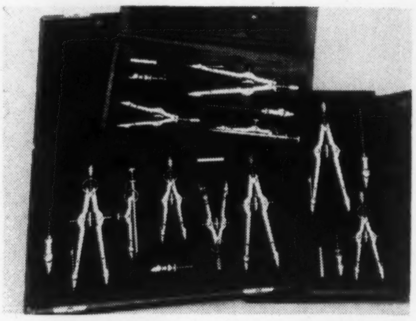
and pens. Sold under the tradename of Vemco, the instruments embody features of open truss design which increases strength and rigidity while cutting weight by 40 per cent. This rigidity enables users to draw extra-large, dense circles in pencil without the instrument yielding. Each bow has a center-screw adjustment which articulates with the legs by cylindrical nuts. Legs bear upon a double-grooved hinge pin of broad base, assuring strength and perfect alignment. Of steel, satin-chrome-plated construction, the instruments are packed in velvet-lined cases.



Blueprint Dryer Is Speedy

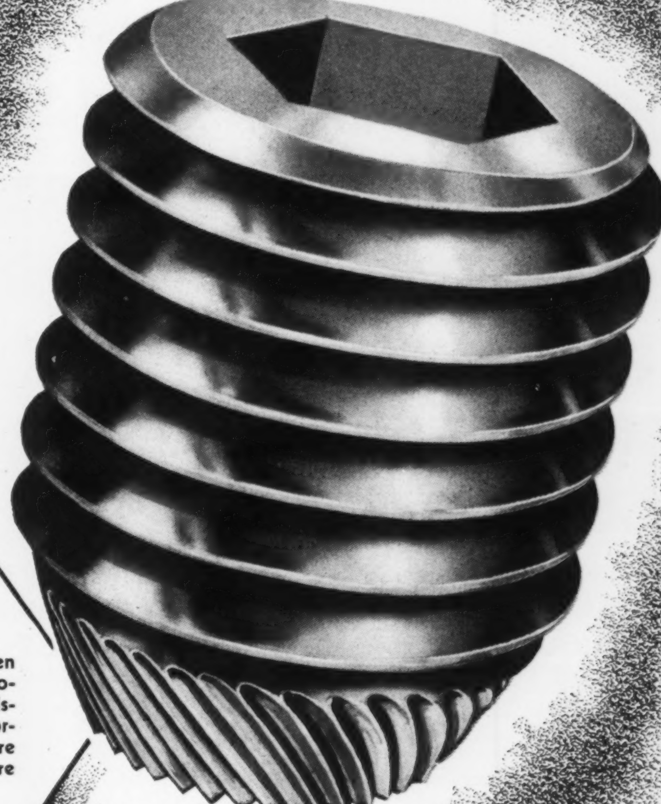
INTRODUCED by The Warren Electric Appliance Co., Warren, Pa., a blueprint dryer will be of interest to machinery manufacturers who use blueprints but must go outside to have them finished. The new dryer permits drying of blueprints on the spot, and is made to accommodate standard 30-inch paper in lengths up to 32 inches. Known as the Weaco dryer, it has a chromium-plated drum which measures 34 x 18 inches in diameter, and has a drying surface of 32 x 52 inches. A blueprint on this machine will dry in approximately five minutes, which is less time than it takes to expose and develop the print. Another feature is its economy of operation. It uses only 700 watts on 115 volts, either alternating or direct-current operation. Strongly constructed, the dryer is said to last for many years, the heating element being guaranteed for five years. Drying belt is made of tough pre-shrunk material. This machine should make a place for itself, particularly in those plants where war work is being done and it is important that secrecy of plans being worked on be safeguarded.

LOCKS AUTOMATICALLY

WHEN TIGHTENED

UNBRAKO

SELF-LOCKING HOLLOW SET SCREWS
with the Knurled Points



A NORMAL pull will tighten the Knurled "Unbrako" so it automatically locks in place . . . a distinct advantage of great importance as there was never a sure way of locking a set screw before "Unbrako" Self-Lockers.

THE Knurling of the point is so cleverly done as to offer no resistance when "Unbrako" is tightened up. As soon as vibration tries to back it off, the Knurls immediately dig in and prevent loosenings. It can't vibrate loose by itself. Further, it can be used again and again, and locks equally well regardless of how often adjusted.

You can eliminate many maintenance costs and breakdowns with "Unbrako" Self-Lockers. Write today for details.

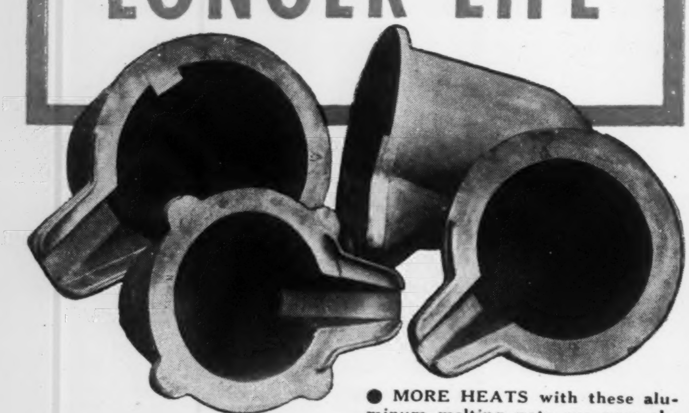
KNURLING of Socket Screws originated with "UNBRAKO" years ago.

STANDARD PRESSED STEEL CO.
JENKINTOWN, PENNA. BOX 102
BRANCHES
BOSTON • DETROIT • INDIANAPOLIS • CHICAGO • ST. LOUIS • SAN FRANCISCO

Send for the "Unbrako" Catalog showing the complete line of "Unbrako" Screws

Reg. U.S. Pat. Office
UNBRAKO
Screw Products

ABSCO MEEHANITE Melting Pots Give LONGER LIFE



● MORE HEATS with these aluminum melting pots are now obtained because they are made of ABSCO Meehanite. Capacities are available up to 2,000 lbs.

You are Assured More Heats with ABSCO MEEHANITE Melting Pots for These Reasons:

1 Special molding methods developed in our foundries result in longer pot life.

2 With the positive technical control of physical characteristics of the metal, made possible with Meehanite, pots of predetermined heat resistant qualities are cast.

Write for a Meehanite Specification Wheel Chart

and full information on Meehanite for Heat-Resisting, Wear-Resisting, Corrosion-Resisting or General Engineering purposes.

Bring us your problems

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BRAKE SHOE AND CASTINGS DIVISION
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NEW JERSEY
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230 Park Avenue, New York, N. Y.
332 South Michigan Ave., Chicago, Ill.

MEN Of Machines

ELECTED president of the Society for the Promotion of Engineering Education, Henry T. Heald, president of Illinois Institute of Technology, will help fulfill the society's planned program to assist engineering schools to fit into the war picture, to maintain close contact with the needs of governmental agencies and to translate those needs into actual production. Born in Lincoln, Nebr., and receiving his B.S. degree from the Washington State College, and his M.S. in 1925 from the University of Illinois, he became instrumentman at the U. S. Bureau of Reclamation. After graduating in structural engineering he was connected with the bureau of design of the Board of Local Improvements, City of Chicago. In 1927 he joined the faculty of Armour Institute of Technology where in 1934 he became dean. He then was made president and remained in this position after the merger of the Armour and the Lewis institutes. Having such a background Dr. Heald will be able to meet the problems confronting the engineering colleges and the society in this war era. In addition to the regular program of maintaining a steady flow of competent engineering personnel, improved handling of instructional and research standards, full utilization of engineering school facilities and personnel for war research, and the continuation of defense training on a high level are primary aims of his administration.

◆

L. E. NEWELL, previously chief experimental engineer, Jeffrey Mfg. Co., Columbus, O., has been named manager of engineering in charge of new designs of the railway equipment manufacturing division, Buda Co., Harvey, Ill.

◆

A. W. HERRINGTON has been elected to serve for three years as a director of the American Society of Military

USER-EXPERIENCE PROVES:

YOU'RE *SURE* OF SPEED WITH BW PRINTS

BLACK LINE PAPER
BW

SUCCESSFUL experience with Bruning Black and White paper throughout the country . . . hundreds of satisfied users in practically every type and size of industry . . . 12 years of praise from users large and small!

No wonder you can be SURE of getting better prints—faster—when you use Bruning Black and White prints instead of blue prints! No wonder you can be SURE that these easier-reading black line prints will give you the speed you require in meeting today's production schedules!

Just two simple steps is all it takes to make a Bruning Black and White print—exposure and development. Time-wasting washing and drying of prints is a thing of the past with BW. You can have big volume production of prints cut to the exact size of your tracings—eliminating trimming and waste.

And you can have the outstanding advantages of Bruning printing and developing machines that give you the very *latest* time-saving advantages—for here, too, Bruning is a pioneer in introducing better equipment for making better prints! Send today for illustrated booklets on the BW process—and ask a Bruning representative to show you why Bruning prints stand FIRST with so many users! Charles Bruning Co., Inc.

This Bruning machine is only one of many which Bruning offers for every size of business or industry. It is automatic in action—exposes and develops prints within a few seconds without washing or drying. It provides big volume production with only a SINGLE *operator—compared to the two or three required to operate the blue print machine of similar capacity.*

2068-251-R

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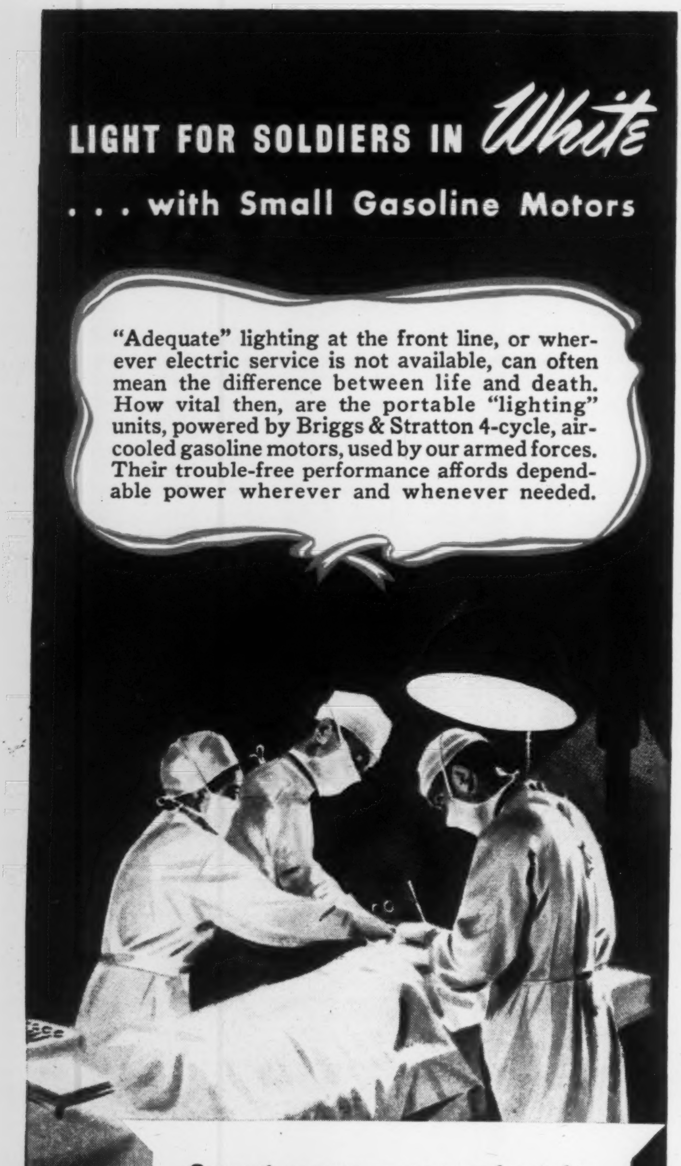
SPEEDS, SIMPLIFIES AND PROTECTS A NATION'S DRAFTING



. . . with Small Gasoline Motors

"Adequate" lighting at the front line, or wherever electric service is not available, can often mean the difference between life and death. How vital then, are the portable "lighting" units, powered by Briggs & Stratton 4-cycle, air-cooled gasoline motors, used by our armed forces. Their trouble-free performance affords dependable power wherever and whenever needed.

Our entire resources are now devoted to supplying Briggs & Stratton gasoline motors, to those whose equipment serves the war program, or is for "essential" civilian uses.

If you're now planning post-war production of gasoline powered appliances and equipment, or if your products fit these classifications, write us and we'll serve you as best we can.

Meanwhile Briggs & Stratton motors (⅔ to 6 HP.) now in civilian use, continue to set new records for trouble-free performance and long life. With reasonable care, their service can be still further prolonged.

BRIGGS & STRATTON CORP.
Milwaukee, Wisconsin, U. S. A.

Engineers. He is president of the Society of Automotive Engineers, was technical adviser to Col. Louis A. Johnson on the recent American Economic Mission to India, and heads the Marmon-Herrington Co., Indianapolis.

◆

George H. Kendall, for the last six years senior commercial service engineer for the Norma-Hoffmann Bearings Corp., recently resigned to devote full time to consulting engineering on war problems of manufacturing, fabrication processes and special machinery development and invention. He formerly was chief engineer for the Bearium Metals Corp.

◆

Founder of the new Ralph Hemphill Research foundation, Mr. Hemphill envisions the primary objective of the foundation, formation of which was announced during the recent opening of the enlarged Hemphill Institute of Technology, as being to foster development of equipment and methods of military value. Prominent in the aviation, plastics and diesel engineering fields, Mr. Hemphill believes that by providing a large corps of engineers and technicians at the free disposal of inventors, as well as experimental shops and laboratories, considerable aid would be given in successfully terminating the war. Other members of the technical board are Thomas M. Shelton, chief of training at the Aero Industries Technical institute; John F. Delmonte, research director of the Plastics Institute of Technology and regular contributor to Machine Design; Ray E. White, chief engineer of the Hemphill institute; and Lieut. W. H. Coffin, operations manager and flight engineer of United Flying Schools of America.

◆

Bruno Loeffler has been made chief engineer of American Bosch Corp., Springfield, Mass.

◆

Dr. Andrey A. Potter, dean of engineering, Purdue university, has been named executive director of the National Patent Planning Commission, Washington.

◆

Racy D. Bennett has become a member of the engineering staff of Vinco Corp., Detroit, builder of machine tools and gages, in the capacity of development engineer. He has been engaged in engineering and consulting service for the last two years and previously was connected for five years with Ex-Cell-O company. L. A. Ward, who has also joined the engineering staff

GLOWELD PASSES RIGID TESTS WITH *High Honors*

Strength and Corrosion Resistance Established For *New* GLOBE Welded Stainless Steel Tubes...

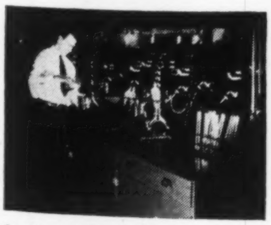
The ability of Gloweld Stainless Steel Tubes to pass exhaustive laboratory tests for corrosion resistance...tensile strength and bursting resistance . . . is important news to the chemical and process industries, food industries, pulp and paper, oil and other industries where these performance factors are vital.

These successful tests, coupled with Gloweld's comparatively lower cost, forecast wider applications for stainless steel tubing.

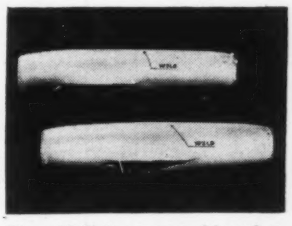
Gloweld is a development of Globe Steel Tubes Co., pioneer manufacturer of stainless steel tubing. It is produced by a closely controlled electric welding process resulting in very little "flash" at the weld, which is removed in a subsequent operation.

Gloweld is available in a wide range of diameters, and wall sizes, in practically all stainless steel analyses. Write for full information.

GLOBE STEEL TUBES CO.
Milwaukee, Wisconsin



Standard laboratory tests, with boiling 65% Nitric Acid, with Nitric and Sulphuric Acids, and by exposure to salt spray, and the Strauss Test, have established the corrosion resistance of Gloweld.



Gloweld Tubes were subjected to pressure until they burst. The weld in every case was as strong as the strip steel.

★ STAINLESS TUBES
★ BOILER TUBES

GLOBE
TUBES

★ CONDENSER AND HEAT EXCHANGER TUBES
★ MECHANICAL TUBING

GLOBE STEEL
Tubes

YOU, TOO, CAN SPEED PRODUCTION WITH THESE AMAZING Kum-Kleen STICKERS

Only magic Kum-Kleen stickers: ✓ are applied without moistening . . . ✓ are easily peeled off without leaving a trace . . . ✓ yet never pop off . . . ✓ adhere to any smooth surface including plastics, metal, glass, wood, varnish, and lacquer.

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of Vinco, has had wide experience in the application of hydraulics to machine tool designs. As chief engineer of the Fox Machine Co. for two years he developed a line of hydraulically operated multiple-spindle drills.

◆

Harold V. Coes, vice president of Ford, Bacon & Davis Inc., has been nominated for the presidency of The American Society of Mechanical Engineers. Nominees for vice presidents include **Joseph W. Eshelman**, president of Eshelman & Potter; **Thomas E. Purcell**, general superintendent, power stations, Duquesne Light Co.; **Guy T. Shoemaker**, vice president, Kansas City Light & Power Co.; and **Walter J. Wohlenberg**, professor of mechanical engineering, Yale university.

◆

King Forbes, formerly design consultant, has joined the Willys-Overland Motors organization as technical engineer of the ordnance division.

◆

Raymond H. Rice, formerly chief engineer, has been elected vice president of North American Aviation Inc.

◆

Harold P. Wade, assistant chief engineer of Packard Motor Car Co., has been named head of the Detroit engineering office of Adel Precision Products Corp., Burbank, Calif.

◆

Bert Cotter has been appointed chief engineer of one artillery carriage section of the Fisher Body division of General Motors Corp., while **Albert Haberer** is chief engineer of the second artillery carriage section. **J. J. Wallbillich** is in charge of the ordnance specialties and machine section.

◆

H. M. Northrop, who for many years has been chief engineer of Hudson Motor Car Co., was recently promoted to vice president in charge of the company's business being conducted in the Detroit automobile plants. Formerly in charge of the engineering department body division, **M. H. Toncray** replaces Mr. Northrop as chief engineer.

◆

Lieut. John A. Bailey is now on active duty in the Office of the Chief of Ordnance, War Department, Washington. He has been an assistant mechanical engineer, Frankford Arsenal, Philadelphia.

◆

Morton S. Umanoff is now assistant mechanical engineer at the Signal Corps Laboratories, Fort Monmouth, Red Bank, N. J. He formerly had been connected with the Picatinny Arsenal, Dover, N. J. as senior engineering draftsman.

◆

I. B. Babcock has been appointed consultant on buses, trucks, and taxicabs to the Materials and Equipment section of the Office of Defense Transportation. He is president of Yellow Truck & Coach Mfg. Co. Other consultants include **Robert F. Black**, president

Designing Molded Plastics Parts: MATERIALS

From the Engineering Files of ONE PLASTICS AVENUE

Although it is primarily the problem of the molder, designers should give consideration to selection of the proper plastics for each application. The following points are intended only as a guide to the principal types in common use:

Molded plastics are divided into two main classifications—thermosetting and thermoplastic.

Thermosetting plastics parts are formed by a chemical reaction resulting from the application of heat and pressure. Such parts are infusible below their burning point.

Thermoplastics are formed by essentially the same process but will not maintain their shape at elevated temperatures.

The thermosetting plastics usually contain fillers, moldability and properties varying with the particular type used. This class of plastics is relatively easy to mold and has dimensional stability over a wide temperature range. Material costs are generally lower than for thermoplastics.

Thermoplastics are used for appearance or where special properties such as toughness, transparency, color range, etc., are required. These materials are subject to cold flow at room temperatures.

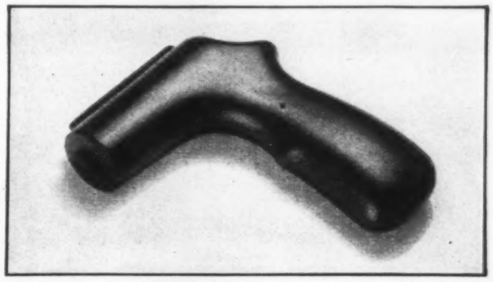
THERMOSETTING

PHENOLICS—Good moldability with wood-flour filler, ranging to fair with rag filler. Little or no cold flow.

Colors in lighter shades are relatively unstable to heat and light. White or pastel colors are unsatisfactory.

Wood-flour filled phenolics are used for general purpose applications. Cotton flock provides improved strength and macerated rag filler is used for greatest impact resistance.

Rag-filled phenolics are more difficult to mold and involve more design limitations.



TYPICAL APPLICATION—In this molded switch handle, two grades of phenolic were used—a general purpose material for the handle grip and a special formulation for the assembly contact end to prevent chipping or splitting.

UREAS—These may be molded in translucent or opaque form in a complete color range, including pastel shades.

Ureas compare favorably with phenolics for electrical properties and have better arc resistance.

More critical cure conditions impose certain design limitations, especially when thick or non-uniform sections are required.

COLD MOLDED—There are two types of cold molded plastics, (1) organic or non-refractory and (2) inorganic or refractory.

The refractory grades are used for applications requiring heat resistance up to 700° C, the non-refractory type for temperatures to 250° C.

Cold molded plastics have unusual heat and arc resistance, other properties are poorer than for phenolics.

Parts may be molded quickly and at low cost. Colors are limited to brown and black for non-refractory, gray for refractory materials. Surface finish is fairly poor and molded parts are comparatively heavy.

MELAMINES—Lower moisture absorption than ureas with good surface hardness and arc resistance.

EIGHT GENERAL CLASSES OF PHENOLICS

- General purpose
- High dielectric strength
- Moisture resistant
- Acid and alkali resistant
- Impact resistant
- Wear resistant
- Heat resistant
- Low power factor

COMMONLY USED FILLERS, WITH APPLICATIONS

Wood flour—general purpose
Cotton flock—impact resistance
Macerated rag—high impact
Asbestos—heat resistance
Mica—dielectric strength
Graphite—minimum friction
Diatomaceous earth—chemical resistance
Barytes—acid resistance
Nut shell flour—general purpose use; more strength than wood flour.

THERMOPLASTICS

CELLULOSE ACETATE—These have good moldability and a complete range of colors and degrees of opacity. Impact and mechanical strength are good. Injection molding method is generally used.

CELLULOSE ACETATE BUTYRATE—The butyrates have the best weather resistance of the thermoplastics. They are the least subject to warping at moderate temperatures and high humidities.

ACRYLICS—The acrylics (Methyl Methacrylate) are crystal clear or colored. They have excellent appearance and dimensional stability, good optical qualities and weather and water resistance. Material cost is relatively high.

POLYSTYRENE—This is the lightest weight plastics and has the best water resistance, with excellent electrical properties and resistance to chemicals. It is comparable to fused quartz as an insulator.

Moldability is good and physical strength is maintained at low temperatures.

CELLULOSE NITRATE—This material is very tough, but applications are limited by its flammability.

COMPARATIVE PROPERTIES OF PLASTICS

KEY A—Excellent B—Good C—Fair D—Poor E—Very Poor	Impact Strength	Flexural Strength	Tensile Strength	Water Resistance	Dimensional Stability	Color Range	Heat Resistance	Dielectric Strength	Moldability
Phenolic	A-C	A-C	C	C	A-B	C	A-B	B	A
Urea	D	A	A	D	D	B	C	A	B
Cellulose Acetate	B	C	D	E	D	A	D	C	B
Acrylic	C	A	C	C	C	A	D	A	C
Polystyrene	C	B	C	A	B	B	C	A	C
Cold Molded	C	D	D	D	B	E	A	C	C

NOTE: Phenolic includes all types.

ADDITIONAL FACTS—Selection of materials is important to the satisfactory performance of finished parts. G.E.'s engineers and chemists will assist you in selecting the proper type for any application. If necessary they will develop new formulations for specific uses.

ONE PLASTICS AVENUE at Pittsfield, Massachusetts, is the headquarters for five plants of the Plastics Department of General Electric Company. It signifies the location of complete plastics facilities for development, material manufacture, designing, engineering, moldmaking, molding and laminating.

REPRINTS of this advertisement may be obtained by writing Section D-9, General Electric, Plastics Department, Pittsfield, Mass.

PLASTICS DEPARTMENT
GENERAL ELECTRIC

PD-21

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25 TRACINGS
IN AN HOUR!"

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Yes, sir, it can be done—25 clear, sharp photocopy duplications *on linen* in quick time. All you need to make an Electro-Copyist tracing is a complete drawing of any kind—a pencil original, a blueprint, a white-print or even an old, worn-out tracing. Think of the vital time you can save in drafting room . . . and in putting the job into production!

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Hunter Original Formula Papers Are HECCO-DYZED

Only Hunter has this amazingly perfect photo-copying paper — especially Hecco-Dyzed with "Original Formula" ingredients to give you ultra-sensitive gradation, light-safety, and clear, even results. Ask for folder describing Hecco-Dyzed linen, vellum and paper.

HUNTER ELECTRO-COPYIST, INC.
431 S. Warren St., Syracuse, N. Y.

of White Motor Co. for fire fighting apparatus and road working equipment, and H. L. Hamilton, general manager of the Electro-Motive division of General Motors Corp., for railroad diesel engines.

◆

Carl A. Ostling has been appointed director of engineering of the United States Rubber Co.

◆

Henry E. Kingman has been made executive vice president of Solar Aircraft Co., San Diego, Calif. Mr. Kingman, who has also been elected a director of the Solar company, resigned as president of the Franklin Management Corp., Boston.

◆

Benjamin T. Salmon has been named chief engineer of Ryan Aeronautical Co., San Diego, Miller T. Boyd is the new chief development engineer and Will C. Vandermeer is chief project engineer. Mr. Salmon has had wide experience as design engineer on airplanes and for several years was project engineer with Glenn L. Martin Co.

They Say . . . .

"The great job of engineers and the engineering societies of today is to out-design the Axis."—Wm. B. Stout.

◆

"The engineer must ever bear in mind the conservation of materials, manhours and machine hours. It is increasingly important that the designs of machines and equipment for the most difficult jobs be so simple that they can be manufactured readily and in sufficient quantities without bogging down our production facilities."—R. C. Muir.

◆

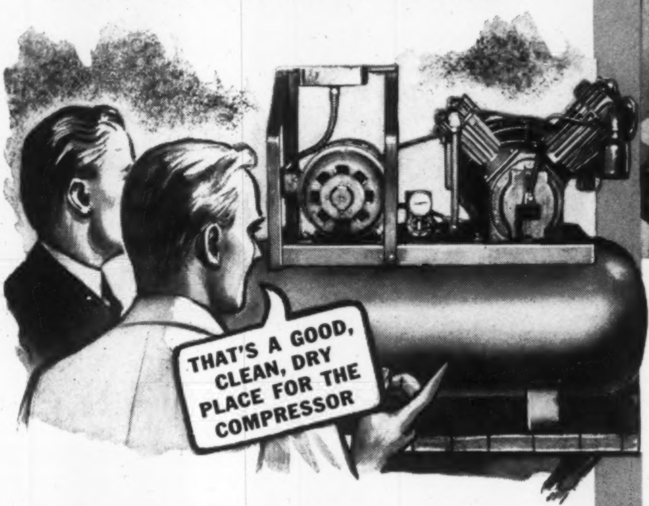
"I am convinced that we have enough materials to win the war—if we use those materials in the most effective way possible. By that I mean that we must make sure that our materials go *where* they are needed *when* they are needed. We dare not waste them, misuse them or let them lie idle. If we allow more materials than are needed in any one place, we shall have less than we need somewhere else. Every demand on our resources must be weighed against all the other demands that have to be made."—William L. Batt.

◆

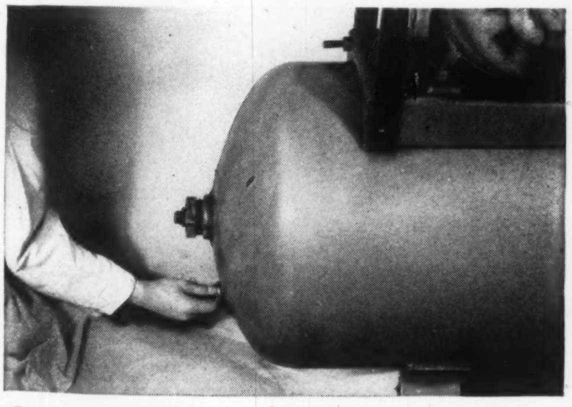
"Mass-produced horsepower is so peculiarly an American ideal that one marvels at the enemy's reliance upon it as a hope for our defeat. For, having goaded patient and peace-loving Americans into a fury of angry action, the enemy has aroused our best minds and hands into using superlative mass-productive techniques of peace for the mass-destructive methods of war."—H. H. Curtice.

DON'T LET NEGLECT SABOTAGE YOUR VITAL LUBRICATION EQUIPMENT!

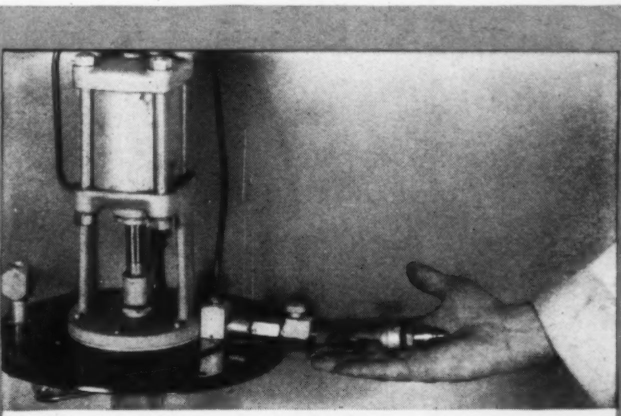
These Five Simple Precautions Can Add Years to the Life of Pneumatic Grease Guns!


THAT'S A GOOD, CLEAN, DRY PLACE FOR THE COMPRESSOR

1 MOISTURE OR GRIT NEAR COMPRESSOR MEANS NEEDLESS WEAR ON YOUR PUMP!
Air compressors should be placed where air is clean and dry. Avoid basements, other damp places, or location near a grinder or other source of dust and grit. Moisture and foreign particles damage pump, cause trouble.



2 TANK SHOULD BE DRAINED WEEKLY!
Condensation in the air line cuts leather, scores cylinder, and causes deterioration of hose. Air tank should be drained *at least once a week!* A petcock is provided for this purpose. This task takes little time, saves much trouble.



3 CLEAN FILTER SCREEN EVERY MONTH!
There is a filter screen at the oiler in most air-operated pumps. This should be cleaned every month, or oftener, to avoid having foreign particles clog the air inlet. Ample air volume at all times is essential to efficient performance. (Be sure your air lines are of sufficient size for your needs.)

4 OIL YOUR PUMP EVERY DAY!
Your air-operated grease pump requires regular lubrication, just as any other machine does. Oil it every day with a medium grade of oil—to insure longer life, to preserve couplers and air valves.

5 CHECK OFTEN FOR AIR LEAKS!
Compressed air is a commodity not to be wasted. Wasted air pressure is wasted power. Audible leaks may require reseating air valve, replacing gaskets or cup leathers to correct sluggish performance of air-operated equipment.

Alemite engineers want to help you get the most out of your vital lubrication equipment. Write to us about any maintenance, repair, or service problem. There is no obligation!

ALEMITE HELPS THE WORLD GO 'ROUND

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Another Product of
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BROTHER THIS IS WAR!

Wartime is no time to gamble ...even on tracing cloth quality

On any job it's bad to be asking, "Is that a 3 or an 8?" On a war job it's inexcusable. The men who work with your blueprints are not "mind readers". Use Arkwright for your transfers – get clear, sharp prints every time – on tracing cloth that will last for years! This strong, uniform, superbly woven tracing cloth is *built* for today's speedy production. Run it through the machine time after time – no curling, fraying, tearing! Next time, specify Arkwright! Arkwright Finishing Co., Providence, Rhode Island.

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TRACING CLOTHS

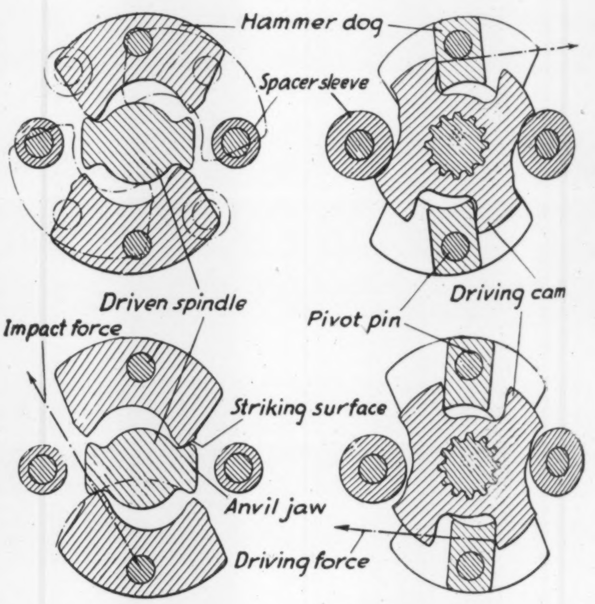
AMERICA'S STANDARD FOR OVER 20 YEARS

Noteworthy PATENTS

Supplies Torsional Impact

TORSIONAL hammer-blows, required in applications such as tightening or loosening threaded connections, may be imparted to a driven member through the use of a patent assigned recently to the Chicago Pneumatic Tool company.

Designed for use with a reversible air motor, the impact clutch consists of a driving cam, a carrier assembly supporting a pair of pivoted hammer dogs, and an intermittently driven spindle. Left-hand views in the figure show a section through the hammer dogs and the driven spindle, while the right-hand views show the driving cam which is co-axial with the driven spindle. The carrier assembly consists of upper and lower plates (not shown) held together by two bolts and spacer sleeves, supporting pivot pins about which the hammer dogs may oscillate.


Hammer dog
Spacer sleeve
Driven spindle
Driving cam
Impact force
Pivot pin
Striking surface
Anvil jaw
Driving force

Momentum of rotating hammer dogs supplies impact force to intermittently driven spindle

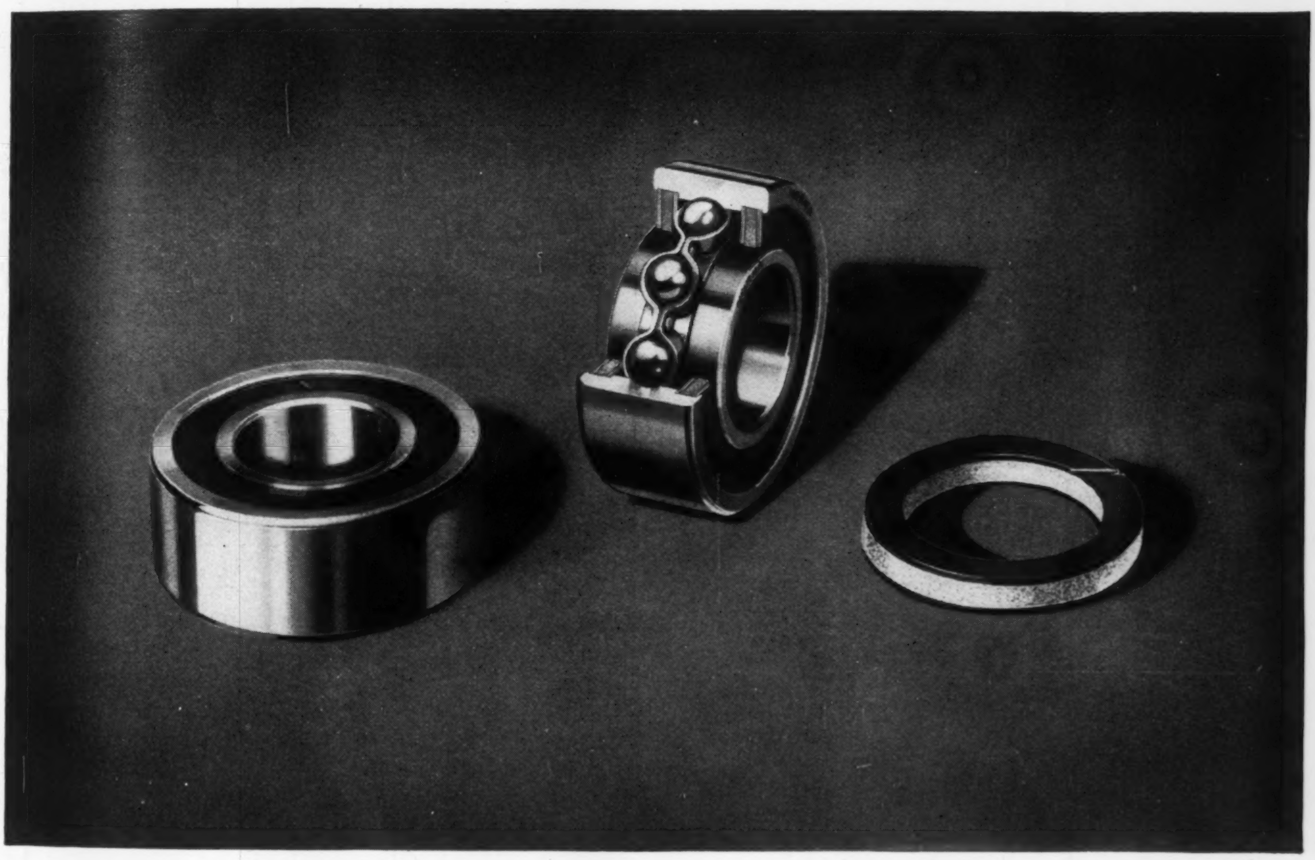
Upper diagrams show the mechanism at the beginning of the cycle. Driving cam bears against the spacer sleeves of the carrier as well as against projections on the hammer dogs, rotating the carrier assembly in the direction indicated by the arrow. Action of the driving force tilts the hammer dogs so that they clear the shoulders or anvil jaws on the driven spindle. Position of the hammer dogs after 45-degree rotation of the

"NORMA-HOFFMANN"

Felt Seal Ball Bearings with

REMOVABLE, REPLACEABLE SEALS

are not only **SMOOTH AND QUIET,** *but also* **EASY TO INSPECT AND REGREASE**



Rigidly fixed in the outer ring, the felt seals in NORMA-HOFFMANN PRECISION BEARINGS are nevertheless easily and quickly REMOVABLE AND REPLACEABLE at will, thus facilitating inspection, cleaning or regreasing.

Moreover, the seal is entirely within the confines of the bearing, and therefore not exposed to injury. The NORMA-HOFFMANN seal construction avoids race distortion, assuring dimensional accuracy and quiet running.

The effective labyrinth formed by the THICK, FULL-SIZE FELT SEALS and plates against the recessed inner ring, provides extra protection against escape of lubricant or ingress of dirt. Grease capacity is ample for long service.

Wide, solid inner and outer rings afford maximum contact on shaft and in housing—making housing inserts unnecessary and militating against slippage, looseness, and escape of lubricant past outer ring.

Write for the Catalog, describing the most complete line of self-sealed bearings in America, including several series with single felt seal, with single felt seal and side plate, and with double felt seal (illustrated above).

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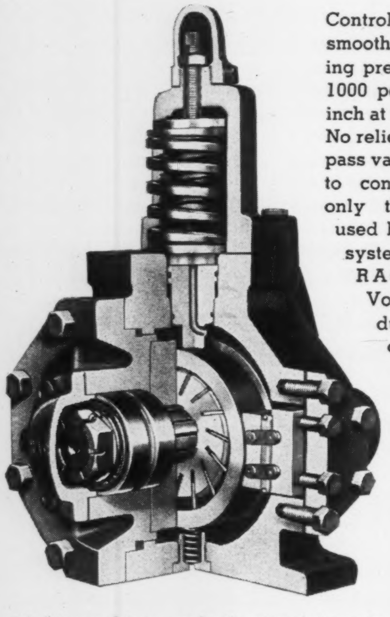
Hydraulic
POWER

with RACINE

Variable Volume Pumps



Controlled Power means smooth efficient operating pressures from 0 to 1000 pounds per square inch at your finger tips. No relief valves and by pass valves are needed to control volume as only the oil actually used by the hydraulic system is pumped. RACINE Variable Volume Pumps reduce horsepower consumption in hydraulic press work, die casting, and metal working. They cut costs and improve performance of materials handling and road working equipment, mining machines, and oil operated equipment of all sorts.

RACINE Variable Volume Pumps are made in three sizes, 12, 20 and 30 gal. per minute, and for operating pressures from 0 to 1000 pounds per square inch. Pressure chamber ring is a hardened steel true circular race that imparts a smooth harmonic action to the vanes. This action gives a continuous powerful non-pulsating flow of oil. Slanted vane slots in the husky rotor make the vanes polishers . . . no gougers of pressure chamber ring . . . greatly increasing pump life. RACINE Pumps are soundly engineered and efficient sources of hydraulic power.

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carrier is indicated by broken lines. Due to the shape of the guide surface on the driven spindle against which the hammer dogs slide, the dogs tilt in such a manner that the spacer sleeves and driving cam separate. The driving force is then wholly through the dogs and the striking surfaces of the dogs are ready to engage the anvil jaws of the driven spindle after sufficient rotation, as shown in the lower diagram.

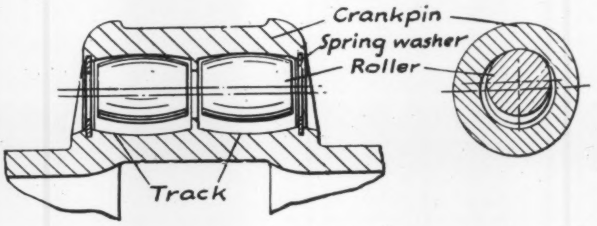
Lower diagrams show the mechanism at the moment of impact. Line of action of the impact force passes through the pivot point of the hammer dog, causing no tendency to rotate out of contact. Driving force, however, has a moment arm tending to tilt the dog out of engagement, but this force is so small compared with impact force that it is insufficient to overcome friction and inertia until the impact force has been almost spent. Tilting action then detaches the hammer dogs, placing the mechanism in the position shown in the upper diagrams, and the cycle repeats.

As the mechanism is symmetrical it will operate with equal effectiveness in either direction of rotation. Furthermore, tendency to wear unequally due to continued action in one direction may be compensated by reversing the dogs at intervals.

Damps Crankshaft Vibrations

Dynamic damping of torsional and longitudinal vibrations in the crankshafts of reciprocating engines without addition of cumbersome damper assemblies is neatly accomplished in a recent patent assigned to D. Napier & Son Ltd.

A moving damper element is located inside the hollow crankpin, and may consist of cylinders, balls or barrel-shaped bodies, either singly or in pairs. The figure shows a pair of barrel-shaped solids of revolution, which may be solid or hollow to suit the requirements of the shaft. Crankpin is bored to a larger diameter than the roller and with a curvature as seen in the longitudinal cross-section such that they may rock in a longitudinal plane.



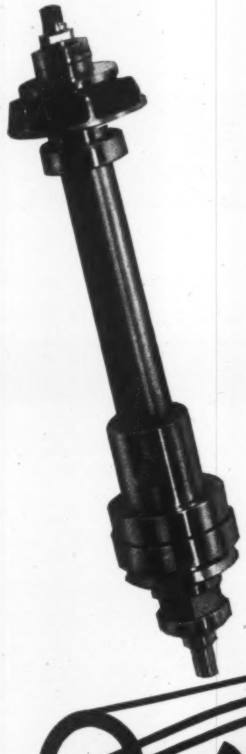
Centrifugal force on crankpin opposes vibration when rollers lag due to inertia

As the crankshaft rotates, centrifugal action forces the rollers to the outside of the track. When torsional oscillation occurs the rollers will tend to lag behind the vibration, rolling against the track so that the centrifugal force exerted against it has a moment tending to oppose the vibration. Action is similar to that in the well-known pivoted-counterweighted type of damper.

Axial vibration is also damped, any longitudinal

Let d = one drop of oil
t = no. seconds
to evaporate d
at 50,000 R.P.M.
To feed exactly
$\frac{d}{n}$ per $\frac{t}{n}$ as $\frac{d}{n}$
approaches 0

Problem . . . . at 50,000 RPM



The problem of lubricating a bearing operating at extremely high speeds is one of supplying minute quantities of oil at time intervals measured in fractional seconds. At 50,000 RPM, for example, a bearing turns 100 times in approximately ⅛ second. Centrifugal force does not allow excess oil to remain in the bearing at such a speed, and a constant supply is therefore demanded. If the bearing runs dry for only ⅛ second, the wear and heat of 100 revolutions is concentrated in that brief instant.

This problem of lubrication has been solved.

Onsrud high speed tools and machines, with bearings revolving as fast as 100,000 RPM, have been working successfully for more than five years, thanks to the patent centrifugal force feed lubrication system known as Onsrud Metered Mist. Millions of machine hours of operation have proved its dependability and efficiency.

For analysis, in relation to the products you are planning today where high RPM rotation is involved, we want to give you the facts about Metered Mist. After the war, we would like to build spindles with Metered Mist construction to your specifications. High cycle electric and air turbine motors will also be available. You are invited to write for a complete report we've prepared on Onsrud Metered Mist lubrication systems.

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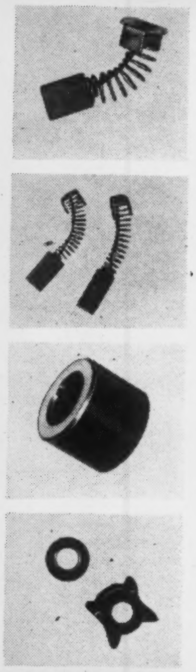
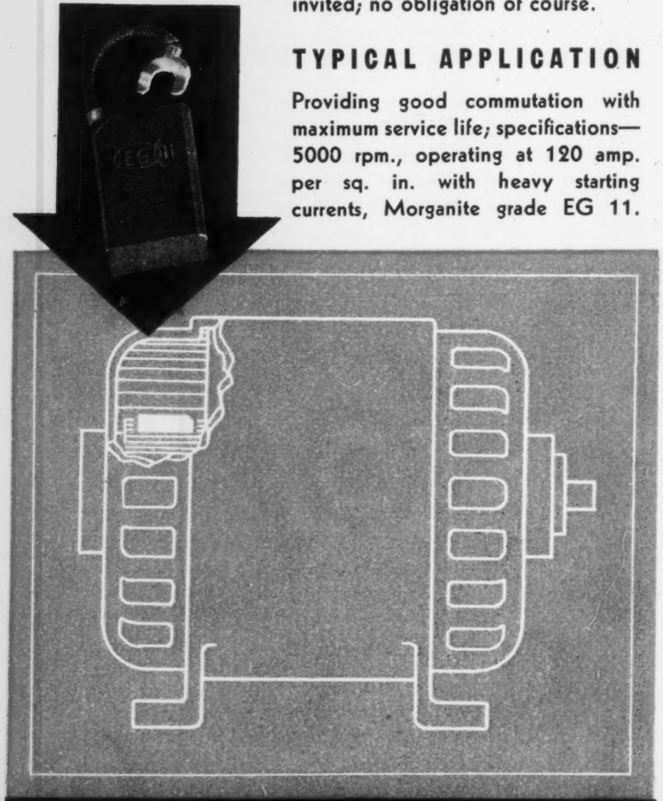
**PIONEER DESIGNERS
AND BUILDERS
OF AIR TURBINE AND HIGH CYCLE
TOOLS AND MACHINES**





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The major role played by MORGANITE products in essential production today, substantiates the research and experience derived over a period of years. This seniority of tremendous importance in vital manufacture, is available to engineers and designers for collaboration in the solution of their problems. Check the inherent advantages of MORGANITE brushes and self-lubricating specialties now. Your inquiries, treated in strict confidence, are invited; no obligation of course.

TYPICAL APPLICATION

Providing good commutation with maximum service life; specifications—5000 rpm., operating at 120 amp. per sq. in. with heavy starting currents, Morganite grade EG 11.

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3304—48th AVENUE, LONG ISLAND CITY, N. Y.

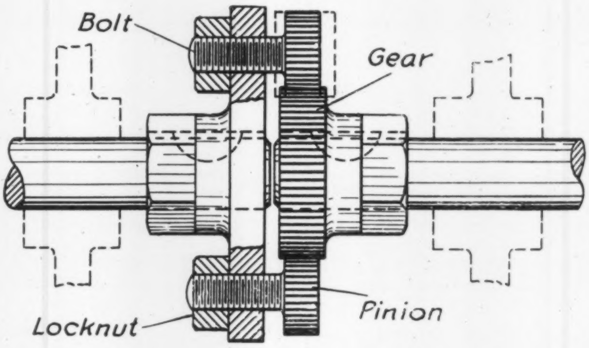
acceleration tilting the rollers and exerting a force on the track with a component in the axial direction.

When forced lubrication of the crankpin must be carried through the shaft, the track is formed on the inside of the plug which is commonly used in engines with hollow crankpins.

Provides Timing-Shaft Adjustment

ACCURATE positioning of two shafts with respect to each other, as required in drives for timing mechanisms, may be secured with infinitely fine adjustment by means of a coupling patented by R. M. Roof.

A flanged coupling element with tapped holes arranged on a bolt circle carries a series of threaded bolts which can be secured with locknuts. The head of each bolt is in the form of a pinion, all of the pinions meshing with a common gear on the other shaft. With the locknuts released, the two shafts may be rotated with respect to each other, utilizing the hexagons provided on the coupling elements. Fine adjustment is made by this means, after which the locknuts are tightened and no further relative movement can occur. Coarse adjustment is made by sliding the large gear out of mesh with the pinions and giving the two shafts the necessary rotation; in this case the angle of rotation can only be a multiple of the pitch angle of the gear.



Gear and planet pinions with locknuts permit fine angular adjustment

---

Made almost entirely of alloy scrap, the new 9400 series of NE steels listed in the table supplements the list published in Machine Design for July 1942.

NE 9400 Steels

SAE or AISI Number	C	Mn	Ni	Cr	Mo
NE 9415	.13-.18	.80-1.10	.20-.40	.20-.40	.08-.15
NE 9420	.18-.23	.80-1.10	.20-.40	.20-.40	.08-.15
NE 9422	.20-.25	.80-1.10	.20-.40	.20-.40	.08-.15
NE 9430	.28-.33	.90-1.20	.20-.40	.20-.40	.08-.15
NE 9435	.33-.38	.90-1.20	.20-.40	.20-.40	.08-.15
NE 9437	.35-.40	.90-1.20	.20-.40	.20-.40	.08-.15
NE 9440	.38-.43	.90-1.20	.20-.40	.20-.40	.08-.15
NE 9442	.40-.45	1.00-1.30	.20-.40	.20-.40	.08-.15
NE 9445	.43-.48	1.00-1.30	.20-.40	.20-.40	.08-.15
NE 9450	.48-.53	1.20-1.50	.20-.40	.20-.40	.08-.15

All of the above steels contain .40-.60 silicon.

Mr. Power Engineer

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Manufactured by AMERICAN FLEXIBLE COUPLING CO., Erie, Pa.

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with
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SPEED
VEROX

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- Full belt contact at all driving diameters.
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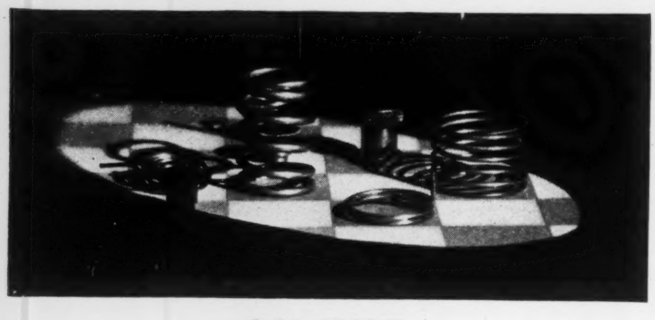

ON THE
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Springs are the *life* of mechanical design. In war products, their ability to function is *life insurance* for our boys! None but the best should be tolerated, even in minor service. Peck Springs proved their high quality in World War I. They are proving it again in the "war of survival." Though our plant capacity is now practically full up, jobs end and must be replaced. If your war product calls for springs, we shall be glad to figure on such as do not exceed 1/8" wire size.

PECK SPRINGS
The Peck Spring Co., 10 Wells St., Plainville, Conn.

Increasing Design Tempo

(*Concluded from Page* 65)

When the loads are such as to cause plastic deformation, or when the stress-strain relations are no longer linear, Young's modulus and Poisson's ratio cannot be used in the list of symbols. The difficulty, however, can be overcome and it can be shown that, if the model is the same material, the loads must be reduced according to the square of the length ratio, that is $P_m/P_p = a_m^2/a_p^2$, and then

$$\sigma_p = \sigma_m, \quad u_p = \frac{a_p}{a_m} u_m, \quad e_p = e_m, \quad R_p = \frac{P_p}{P_m} R_m$$

The fact that the displacements in the model are in proportion to the scale means that geometrically similar specimens will deform to the same shape at corresponding loads, or at the same stress. The simplest case is that of the tensile testpiece. This similarity of the deformed shape of different sizes of testpiece at the same stress has been confirmed and is known as "Barba's Law". Curves for rubber springs relating P/a^2 to the average unit strain, or an angular deflection, both of which are dimensionless, will be the same for larger or smaller similar springs of the same rubber.[8]

Plastic Action Requires Same Material

In plotting load-displacement curves for plastic processes, or for cases where there are both elastic and plastic regions, it is not possible to plot u/a against P/Ea^2, since there is no E. The same material must be used for the model and then it is sufficient to plot P/a^2, which of course is not dimensionless, against u/a. If the same unit system is used, the curve is the same for all the members of the similar set. The conclusions as to buckling are that, when the model is made of the same materials, buckling occurs at the same value of P/a^2, or at the same applied stress. Curve III in *Fig.* 3 illustrates the kind of curve obtained for columns buckling after the proportional limit has been passed.

In *Fig.* 4 is shown a stress-deflection curve[9] for a compressed rubber block. Dimensional analysis shows that although the stress is not dimensionless and Hooke's law is not obeyed, the curves should be the same if geometrically similar blocks of different sizes but of the same rubber are tested, i.e., no size effect.

Nadai (see footnote 7) quotes, as an example of similarity in elastic-plastic systems, the case of a set of balls indenting blocks. If the material is the same for all the balls and for all the blocks, and if the loads are as the squares of the ball diameters, the stresses will be the same at corresponding points and the depth of the indentations and the diameters of the plastic zones on the block surface will be as the diameters of the balls, provided the effects of time of loading are negligible.

---

[8] Formulas used in the design of such springs commonly assume uniform stress at the bond with the metal mounting. This will usually be untrue, and the distribution of stress is liable to change with load when the stress-strain relation is not linear. The dimensional argument shows that there are simple similarity rules in spite of these complications.

[9] "From Rubber and Rubber Mountings"—J. F. Downie Smith, *Journal of Applied Mechanics* (*Transactions*, A.S.M.E.), March, 1938.

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Don't accept slow deliveries

of cold drawn tubing until you have investigated *all* the possibilities of hot finished tubing.

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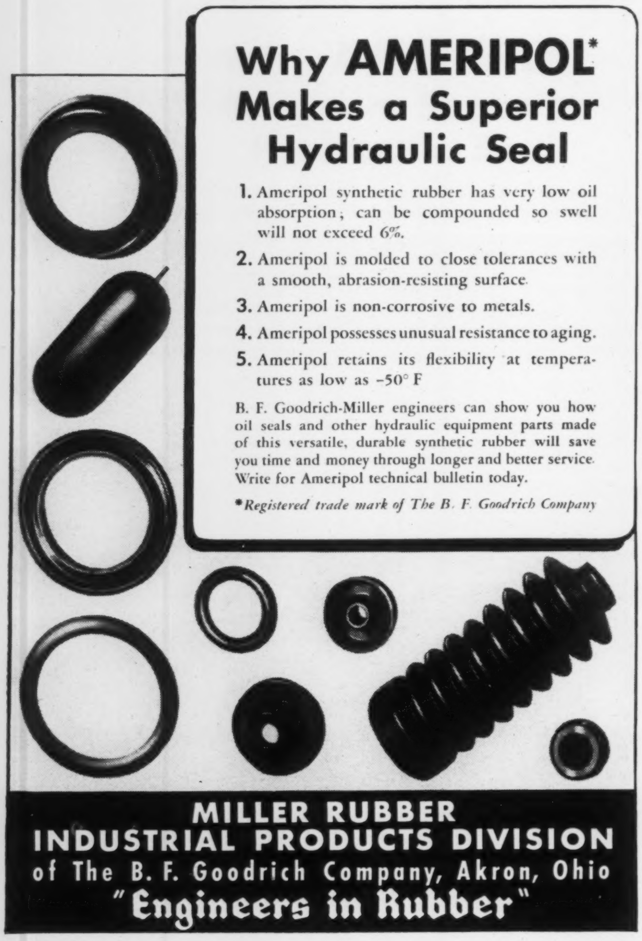
Why AMERIPOL* Makes a Superior Hydraulic Seal

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B. F. Goodrich-Miller engineers can show you how oil seals and other hydraulic equipment parts made of this versatile, durable synthetic rubber will save you time and money through longer and better service. Write for Ameripol technical bulletin today.

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MILLER RUBBER
INDUSTRIAL PRODUCTS DIVISION
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"Engineers in Rubber"

Which Thermostat?

(Concluded from Page 69)

and Bourdon tube with its variations such as spiral and helix. The diaphragm is usually restricted to applications requiring less than ten pounds, whereas the bellows are applied up to 75 pounds and Bourdon tubes or variations from 75 to 2000 pounds.

For indicating and recording instruments, most temperatures are measured with the spiral or helix type. Only for sensitive instruments are diaphragms or bellows required. For power applications such as operating a switch, relay or valve, the direct stroke of a bellows has useful advantages.

Accuracy Needed for Spring Tubing

Spring tubing for spirals and helixes must retain its accuracy throughout the life of an instrument. The tubing is formed elliptical before being curved to shape and embraces sizes ranging from .125-inch to .75-inch diameter with walls as thin as .005-inch. For low-pressure work, copper and its alloys are employed. Of the steels, chromium-molybdenum series is widely used. Where corrosion is encountered, 4-6 per cent chromium with .5 per cent molybdenum is frequently used, and for severe corrosion 18-8 stainless and stainless-molybdenum with 16 per cent chromium, 13 per cent nickel and 3 per cent molybdenum is employed. Stainless grades involve difficulties because their physical properties must be obtained by cold working instead of by quenching and tempering as for other steels.

Bellows are invariably copper alloy and usually are formed from a single seamless extrusion. Action is linear and is easily controlled. Change in calibration or operating range is affected by adjustment of a bucking spring. Also, if desired a bellows can be converted from a direct-acting unit to a reverse control by linkage arrangements.

For units where the bellows itself is the thermal-sensitive element, neither the capillary tube nor the bulb are employed. Units of this type controlling operating temperatures of liquid-cooled engines in trucks, tanks and aircraft have a direct linkage to a butterfly or poppet valve and operate on a differential of 25 degrees Fahr. These thermostats are calibrated to within 5 degrees and have strokes up to ½-inch.

With the wide selection of temperature controls and their various characteristics when utilizing bimetals, pyrometers or pressure-bulb thermometers, there is a best design for each application when costs, operation and life are considered.

Extensive help from the Powers Regulator Co. and the Brown Instrument Co. in the preparation of this article is gratefully acknowledged. Also, the cooperation of the following companies in supplying information is highly appreciated: Bishop & Babcock Mfg. Co.; Clifford Mfg. Co., *Fig.* 3; The Foxboro Co.; Julien P. Friez & Sons; The Fulton Sylphon Co.; General Electric Co., *Fig.* 1; Summerill Tubing Co., *Fig.* 4.

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PRODUCTION

On Your Sub-Contracts for Fabricated Metal Parts

This Brochure will enable any producer of War Materials to determine where Lyon facilities can help accelerate production through sub-contracting. A copy is yours for the asking.

● When you turn to Lyon for quick, positive co-operation on expediting War Contracts involving sheet metal products, teamwork by Lyon's War Products Committee assures time-saving, intelligent action.

This committee has worked as a team on this highly specialized job for more than a year. It provides a practical knowledge of War Work requirements that saves time and eliminates false steps.

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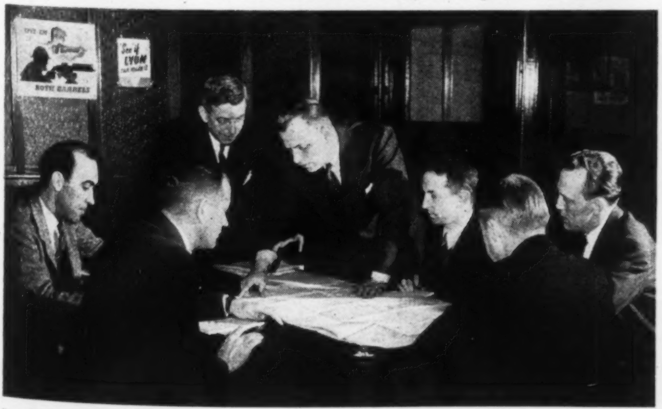
The Lyon War Products Committee — which meets daily — has more than a year's experience expediting War Contracts. Its record for getting results has won widespread press comments.



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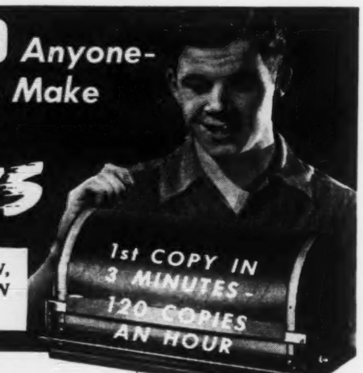
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Refining lubricating oils • Operating automatic checks on machine tools • Testing instruments • Operating milking machines • Paper feeding, printing-presses.

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Industrial oil burners • Spraying paint or chemicals • Atomization of liquids • Generating cooking gas from liquid fuels—and many hundreds more.

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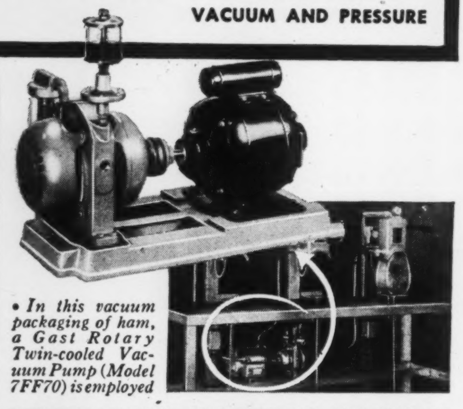

• *In this vacuum packaging of ham, a Gast Rotary Twin-cooled Vacuum Pump (Model 7FF70) is employed*

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● Manufacturers who bring their pump problems to us find Gast engineered-to-the-job pumps step up performance, reduce operating troubles and increase output. The unique Gast Rotary design provides a more efficient, lower cost operating unit, specially, designed for your machine and embodying these features: 1-Smooth, non-pulsating steady flow of air. 2-Forced-Air-Cooling, supplying greater air volume without complicated water systems. 3-Automatic Take-Up, which compensates for wear. 4-Compact design, saving space and weight.

Complete Line *includes 12 sizes, Gast Rotary Air Pumps, ½ to 23 C.F.M. Vacuum to 28". Pressures up to 30 lbs.*

Send for catalog containing specifications, engineering data and performance tables

GAST MFG. CORP.
107 Hinkley St.
Benton Harbor, Mich.

Wartime Metallurgy

(Concluded from Page 74)

precisely as described for dissolved atoms. To illustrate, if the atoms of a solute were diffused throughout the solvent and then some change suddenly occurred to the solvent so as to enable it no longer to hold the atoms in solution they would drop out of the lattice structure. If they formed a compound with the solvent they would then unite with it to form molecules of the compound. Assuming another change in the solvent occurred to stiffen its structure so that the molecules could not move about, the foreign matter would then be present in a state of "molecular dispersion" and the keying effect would be the same as in the case of the atomic dispersion.

There is one important difference, however. Whereas in the solution the stable condition is uniformly diffused, in the second case the tendency is for the molecules to agglomerate. If the structure of the solvent be softened to permit some degree of mobility to the molecules they will gather together into as large masses as the mobility will allow.

The foregoing covers, in brief, the fundamentals of hardening by heat treatment. The solvent is gamma iron, the solute is carbon. When the temperature is lowered, causing the iron to transform from gamma to alpha, the carbon is thrown out of solution because the alpha iron has not the ability of the gamma iron to hold the carbon. This precipitated carbon then combines with atoms of iron to form the compound Fe_3C. If the cooling is slow the molecules of the compound will be agglomerated and the metal will be but little strengthened. If, on the other hand, the cooling is so rapid as to lower the solvent to the point where the compound may not migrate, it remains in fine dispersion, hardening the metal. The details of this, and other phases of hardening phenomena, will be the subject of the next article of this series.

To sum up the significant facts of this discussion, they are: Within the crystal—the regularity of the atomic structure, the atomic planes due to this regular structure along which slip may readily occur, the possibilities of keying these potential slip planes by foreign atoms and by the lattice distortion of work hardening. Without the crystal—the effects of the boundaries in interfering with slip and from this the greater strength of fine grain size, the forcing of nucleation by rapid extraction of heat, the fragmentation of the grains and their reformation in hot work, and the fragmentation and lattice distortion without reformation (except in heating) in cold work. To this is to be added the statistical isotropy that may be assigned to a large group of grains, the atomic dispersion and diffusion of the dissolved matter in a solid solution and the aggregate nature and the tendency to agglomerate of insoluble matter. Concerning iron itself, under stable conditions, one crysal pattern is present above the critical temperature and another below. Upon this groundwork of theory, hardening of iron and steel by heat treatment will be discussed in the later articles.

AN EXCITING PREVIEW OF THINGS TO COME FROM

GLASS

Our research laboratories and design department are humming these days, exploring with priority-pinched industries new and practical uses of glass. It's an exciting preview to many promising postwar products.

Take our experiments with kitchen stoves, for example. Here, as with so many products, the study of glass as a replacement material has opened the way to revolutionary new design and performance features.

This new experimental stove features a full-vision oven door and top made of heat-strengthened Tuf-flex plate glass . . . the glass with the iron constitution. The inside of the oven is lined with colored opaque structural flat glass. The glass at the back of the oven and on the instrument panel is of a translucent type with indirect lighting, providing shadowless illumination. Housewives and stove manufacturers will instantly appreciate the utility features of this completely lighted, full-vision oven.

The new glass stove features suggested here can be accomplished with standard L·O·F glasses, the result of years of exhaustive research by our company. From our complete line of glass products we are able to fit glass into scores of special applications. There are L·O·F glasses with thermal, acoustical, structural, lighting, decorative and many other chemical and physical properties that fit this remarkable material for endless uses.

If you have a material or design problem, we will welcome the opportunity to explore with you the possibilities of continuing your product with glass. Libbey·Owens·Ford Glass Company, 1359-A Nicholas Building, Toledo, Ohio.

L O F

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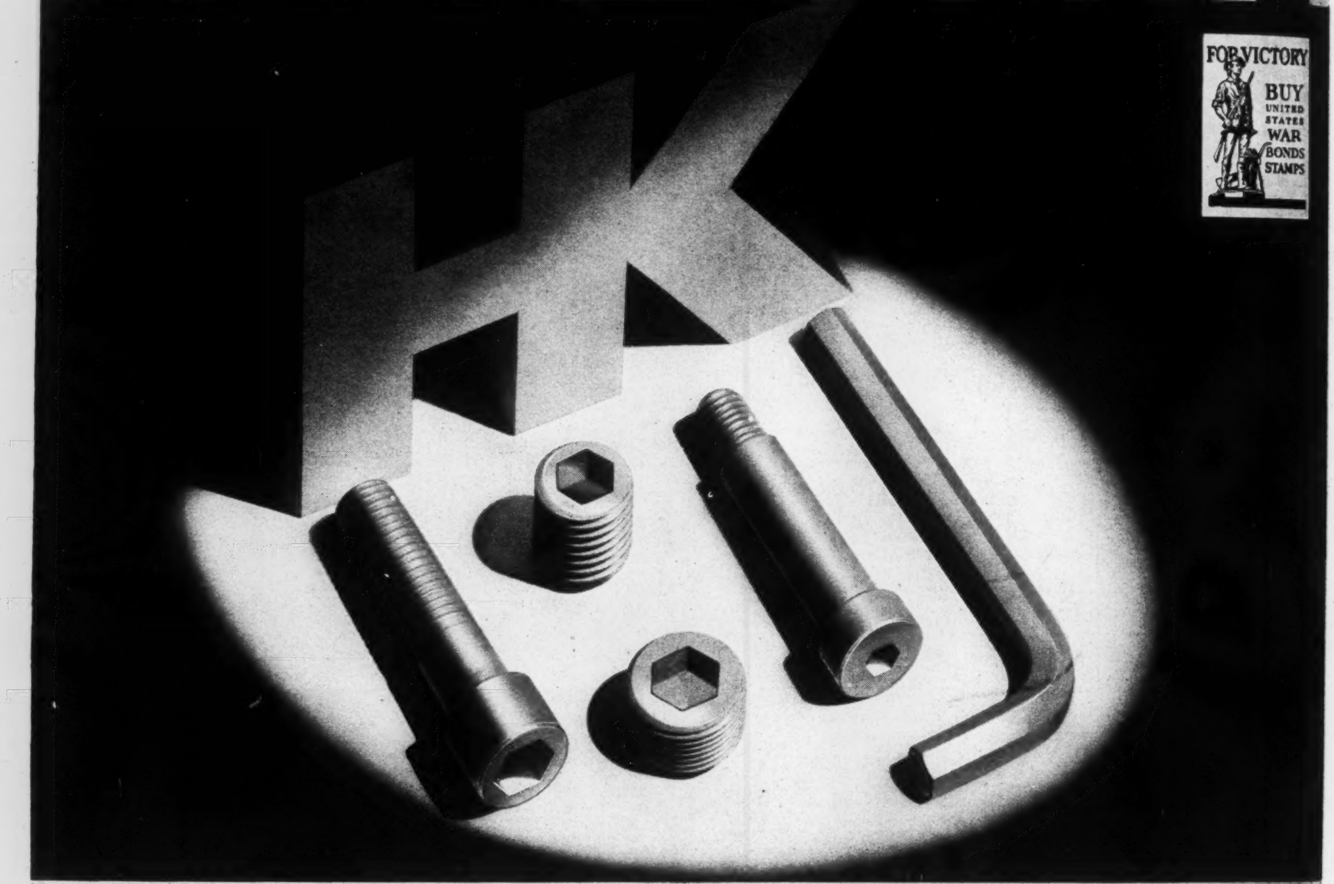
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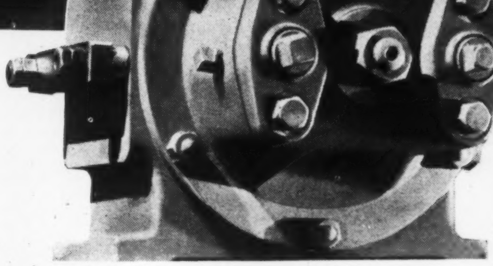
SMOOTH AS A GUN BARREL

Official U. S. Navy Photograph

Hele-Shaw Fluid Power smoothness reduces vibration, cushions shock, makes machines last longer

Smoothness—that's one advantage of Hele-Shaw Fluid Power we can get across in few words. You see, Hele-Shaw Fluid Power is simply oil under pressure from a Hele-Shaw pump. It's used to power hundreds of different types of hydraulically driven machines. The Hele-Shaw pump is a rotary, radial, multi-plungered pump. The power it delivers flows smoothly to the driven ram or plunger. Then, too, using oil, the pump and the system, are self lubricated. The oil also serves to cushion the driven machine or machine-tool against shock. Fluid Power reduces vibration, absorbs shocks, lengthens life of machine, cuts manufacturing time and maintenance. Look up this and other advantages of Fluid Power in the Hele-Shaw Pump Catalog—it's yours for the asking.



THE

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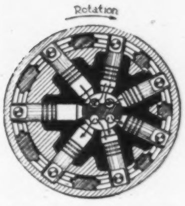
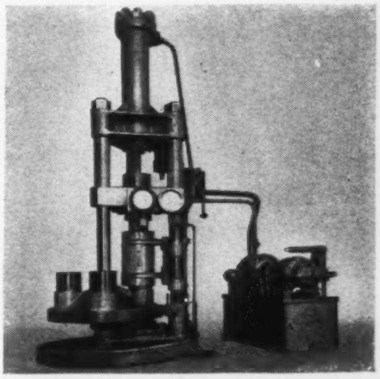
Fluid Power Pump



Cross sectional view of the Hele-Shaw Pump showing the multiplicity of plungers which are responsible for the smooth, even flow of Hele-Shaw Fluid Power.



HYDROSTATIC SHELL TESTING PRESS, built by the Baldwin Southwark Division, Baldwin Locomotive Works, Philadelphia. A feature is the individual Hele-Shaw Fluid Power pumping unit, permitting easy relocation of machine.

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EXTREME STRENGTH

These quick-action toggle clamps are the only drop forged clamps available—they last longer—it pays to specify them.

MODELS ILLUSTRATED—*Top:* Quick-Action Toggle Clamp—handle is down, out of the way, when holding work. • *Center:* Extreme Leverage Double Toggle Clamp—opens fully for complete clearance of work. • *Lower:* Extended Base Toggle Clamp—used as a "C" clamp or, when provided with stops, becomes a jig in itself.

Products Engineering Co's Drop Forged Clamps are available in many other models and sizes from midget to 6" clamping bar. Send for catalog on clamps and other production tools.

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Practical Aspects of Bearing Design

(*Concluded from Page* 87)

controlling factor in bearing design, because it is proportional to the rate at which heat must be removed from the bearing.

For instance, if in two bearings it is found that the unit loading, minimum film, and oil temperature rise are all within the limits imposed, but that one bearing shows $p_s = 50$, and the other $p_s = 500$, it could well be expected that the bearing carrying the higher value is apt to give trouble in service while the former should give long life and be trouble free. This analysis is based on the assumption that both bearings are fabricated with either tin base or lead base babbitt. We have not yet had sufficient experience with other bearing materials to establish a rating.

Partial Bearings Improve Performance

When the design permits, a lower power loss and a greater bearing capacity may be obtained by the use of partial bearings instead of full journal (360-degree) bearings. This is because of the lower length to width ratio (length in direction of motion to bearing width—not the same as L/D). Further comment is not needed here, as an examination of Howarth's data (1) will show rather complete information. Needs' data (2) should also prove useful, although this is limited to 120-degree bearings centrally loaded. We have recently made some computations and have also conducted tests on two 60-degree partial bearings as against a 180-degree bearing. *Figs.* 1 and 2 show the results of the tests. The partial bearings have run three times as long as the 180-degree bearings, and are still in perfect condition. Calculations showed that the two partial bearings would have less than one-half the power loss and 1.68 times the maximum capacity. If the 180-degree bearing were designed with the same l/w ratio it would be 78 per cent wider than the partial bearings, with the power loss increased 2½ times. The experimental evidence appears to bear out the validity of the computations.

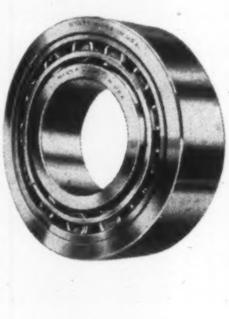
REFERENCES

1. "Loading and Friction of Thrust and Journal Bearings with Perfect Lubrication"—H. A. S. Howarth, *Transactions*, A.S.M.E., Vol. 57, Page 169, 1935.
2. "Effects of Side Leakage in 120-degree Centrally Supported Journal Bearings"—S. J. Needs, *Transactions*, A.S.M.E., Vol. 56, Page 721, 1934.
3. "Film Lubrication Theory and Engine Bearing Design"—E. S. Dennison, *Transactions*, A.S.M.E., Vol. 58, Page 25, 1936.

YOUNG college women are being trained by General Electric to do work formerly done by male engineers. Two of 150 recently hired have engineering degrees. Although it is not expected that these women will become full-fledged engineers, no one can predict how important their work will become during the war or even in the postwar period.

HERE'S HOW TO
KEEP 'EM
ROLLING

YOUR ROLLER BEARINGS HAVE A BIG JOB TO DO. DON'T NEGLECT THEM! KEEP THEM CLEAN . . . WELL LUBRICATED . . . PROPERLY ALIGNED! THIS IS NO TIME TO TAKE CHANCES!



WHILE anti-friction bearings keep factory wheels turning, transportation rolling and farm machinery producing, they have the added wartime job of keeping armies on the go, aircraft aloft and battle fleets afloat.

Vital to the arming, transporting and feeding of our forces . . . with Victory demanding round the clock operation, day after day . . . even sturdy bearings like Hyatts, *which run for long periods without attention under normal conditions,* need a little care today.

Be sure bearings are properly sealed and lubricated. Be sure bearings fit snugly...for looseness might cause excessive wear and misalignment. Keep bearings free from grit and dirt both in assembly and in operation.

With Hyatts assigned to two important jobs: beating friction and helping to beat the Axis...don't neglect them! Our Engineering Department will be glad to help you on any bearing application or maintenance problem.

Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey.

THIS IS THE 50TH YEAR OF HYATT ROLLER BEARINGS

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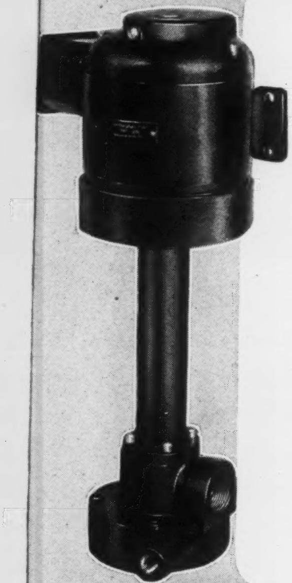

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With today's production demands "upped" your machines need the assured-flow advantages of Eastern Coolant Pumps. These features protect the output of your machines:

- Open-type impeller provides adequate clearance for passage of chips and abrasives.
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Business and Sales Briefs

ALL activities in connection with the promotion and sale of G.E. motors, controls and other electric apparatus to the machine tool industry have been placed in charge of W. R. King, according to an announcement by S. W. Corbin, manager of sales, machinery manufacturers section, industrial department of General Electric Co. Mr. King has been associated with the company since 1928 when he joined it as a student engineer.

◆

The Fostoria Pressed Steel Corp., Fostoria, Ohio, is celebrating its twenty-fifth anniversary. Born during the World War, the corporation includes approximately 40 distributors.

◆

Formerly of Chicago and New York, R. E. Powers has been named Pacific coast district manager of the manufacturing and repair department, Westinghouse Electric & Mfg. Co. Mr. Powers is being transferred to Emeryville, Calif., from Chicago where he has been for the past four years. He will have charge of all activities of his department in a territory comprising all or parts of 11 western states, Alaska and the Hawaiian Islands.

◆

Dan C. Hungerford has recently resigned as vice president and director of Elastic Stop Nut Corp., Union, N. J. He has been with the corporation since 1936 when he joined as field engineer. In 18 months he was made chief engineer, and in 1940 was elected to the board of directors. In July of that year he was made vice president in charge of engineering.

◆

Manufacturing rights for Meehanite castings have been granted to E. W. Bliss Co., Brooklyn, N. Y., by Meehanite Metal Corp. The Bliss company will produce these castings at its foundry in Hastings, Mich.

◆

Fred Jessop Wood has been assigned to take over the duties released by Howard M. Dawson, at the Detroit sales office of Jessop Steel Co.

◆

Transfer of H. S. Landon, for the past eight years Chicago and western district sales manager of Ohio Ferro-Alloys Corp., has been made to the general office of the company at Canton, O., as general manager of sales. The Chicago office at 1740 Conway building will be in charge of B. A. Patch who has been in that territory for some years.

◆

Resignation of M. E. Clark as sales manager of the Randall Graphite Products Corp., Chicago, has been

When this much copper will carry the electric load and protect from corrosion--it is wasteful to use this much for mechanical strength. Copperweld can use this much copper and this much steel---and do the same job with a clear saving of 70% copper.

COPPERWELD STEEL COMPANY · GLASSPORT, PA.

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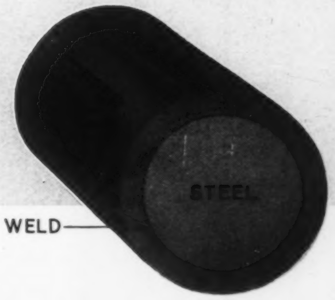
(COPPER-COVERED STEEL)



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(14 to 96 D.P.)

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With full *production capacity* scheduled far into the future, all new inquiries are now necessarily subordinated to these vitally important prior commitments. However, every *urgent* need will be given careful consideration.

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Exclusive rubber cushion made with oil-resisting treatment and gripped permanently by die-cast ends combines positive drive with resilient protection against misalignment and free end float. No parts to get out of order, become noisy, need replacement or lubrication. No backlash.

Write or wire today for testing sample and complete information.

GUARDIAN FLEXIBLE COUPLINGS
212 E. MICHIGAN ST. MICHIGAN CITY, IND.

announced. He has been commissioned a major in the Ordnance Corps. His successor has not as yet been appointed.

◆

F. H. Lindus has returned to the sales department of the Timken Roller Bearing Co. service division at its San Francisco branch.

◆

Recently Robert H. Morse Jr. has taken a position as assistant sales manager with A. C. Dodge, vice president and sales manager, Fairbanks, Morse & Co., Chicago. Mr. Morse has been branch manager successively of the company's offices at Cincinnati, Dallas and Boston. John Elmburg, formerly manager of the diesel engine department at St. Paul, has been made manager of the Boston branch to fill the vacancy left by Mr. Morse.

◆

Lindberg Engineering Co. has made Robert C. Onan district sales manager for their Northern Illinois, Iowa, Wisconsin and Minnesota territories.

◆

Jones & Laughlin Steel Corp. has appointed H. E. Robinson as manager of its strip sheet sales department, replacing A. J. Hazlett who has become assistant general manager of sales. Mr. Robinson was formerly vice president in charge of sales, Otis Steel Co., Cleveland, which is now the Jones & Laughlin Otis works.

◆

Election of Frank J. Hill as vice president of Greene, Tweed & Co., New York, manufacturers of mechanical packings, has been announced. He has been connected with the company since 1915 and has been its sales manager for many years.

◆

Transfer of K. J. Pederson to Charlotte, N. C., to handle sales in North and South Carolina has been announced by Acme Steel Co., Chicago. He has been associated with Acme for twenty years. His headquarters will be at 2243 Selwyn avenue.

◆

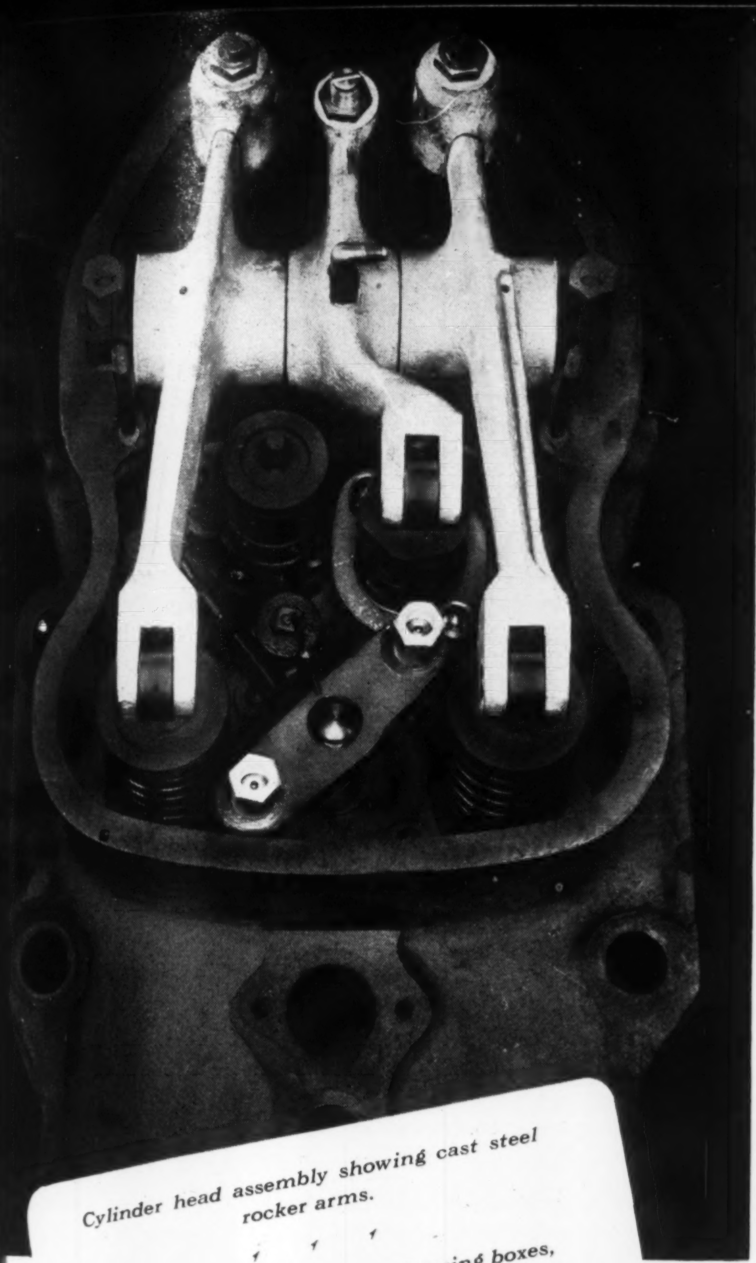
Previously assistant manager of sales, bolt and nut division, Republic Steel Corp., Cleveland, R. J. Schuler has been appointed general manager, Hampshire Products Inc., Milan, Mich.

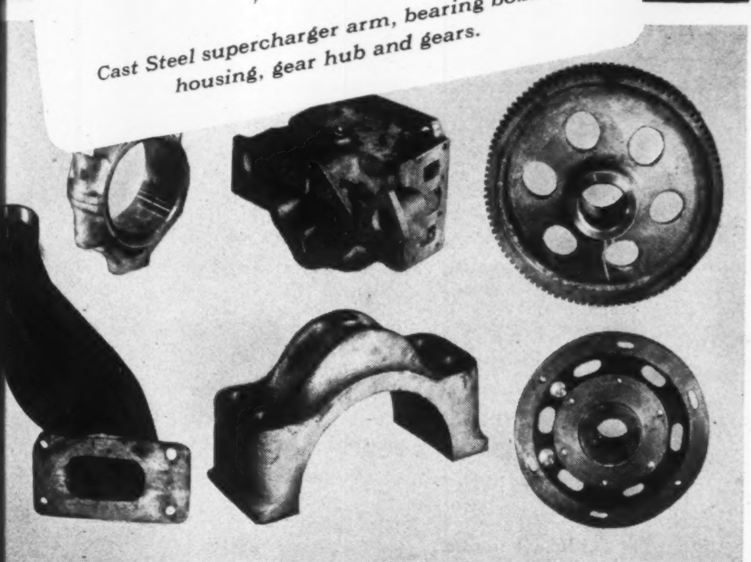
◆

Announcement has been made of the appointment of R. J. Hearn as assistant manager of the Boston district office of Crocker-Wheel Electric Mfg. Co. An electrical engineering graduate, Mr. Hearn joined the organization about two and a half years ago as a field engineer, specializing in the application of motors for machine tool drives. He formerly was connected with Allis Chalmers as sales and service engineer.

◆

In Allegheny Ludlum's Detroit district sales office, J. D. McKnight has been named manager, according to R. M. Allen, the company's general sales manager. Formerly assistant manager in Detroit, Mr. McKnight





Cylinder head assembly showing cast steel rocker arms.

Cast Steel supercharger arm, bearing boxes, housing, gear hub and gears.

Diesel Power

DEPENDS ON

CAST STEEL

Vital parts of the Diesel engines that drive trains and ships and trucks are steel castings. These rarely-seen arms and gears and valves and housings deliver unfailing production of power, maintaining their precision fit, and their resistance to high pressure, wear, heat, vibration and fatigue.

Wherever tough conditions must be met by metals, steel castings are giving faultless performance.

From small parts precisely shaped to close tolerances, to large structural members weighing tons, castings are the most economical means of securing the many desirable properties of steel.

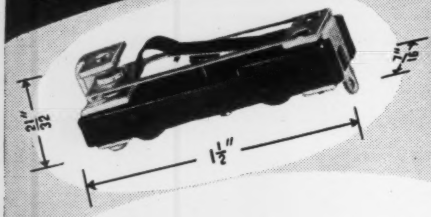
They help to speed up manufacture—to save time in finishing and assembly. Often they are complicated shapes that could not be economically produced by any other method. They afford almost infinite variety of mechanical properties readily obtainable by using different heat treatments and alloy additions. They may be perfectly welded in composite structures.

If you'd like to have your own products analyzed, to see where steel castings can make them better or less costly to build, consult your own foundryman, or write to Steel Founders' Society, 920 Midland Bldg., Cleveland. No obligation of course.

MODERNIZE AND IMPROVE YOUR PRODUCT WITH

STEEL CASTINGS

Announcing NEW Acro Snap

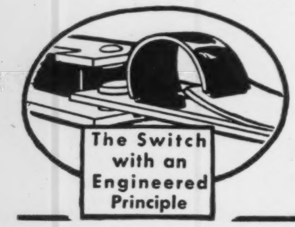


MIDGET SWITCH

Weight: 7¼ Grams
Gap: .040 Inch

When the large electrical manufacturers wanted a small snap-action switch they came to ACRO. Hence this Midget Switch.

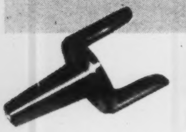
- It embodies the unique ACROSNAP Principle of the rolling spring to snap the blade from one position to the other.
- Operating with very slight strain it has exceptional performance and long life.
- It enjoys positive operation on very slight plunger travel.
- Its small size adapts it to many installations in which the standard model cannot be used.
- Furnished in single pole construction, with normally open, normally closed or double throw contact.


The Switch with an Engineered Principle

Write for characteristics in A.C. or D.C. operations.

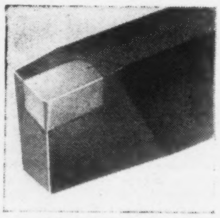
ACRO ELECTRIC CO.
3179 Fulton Rd., Cleveland, Ohio

IS TOOL BREAKAGE On JUMP CUTS Forcing You To COMPROMISE on DESIGN?



KENNAMETAL*
CAN SOLVE YOUR PROBLEMS

If excess tool breakage because of interrupted cuts is increasing your production costs, KENNAMETAL can help you. Due to the high rupture strength, hardness and "non-cratering" qualities of KENNAMETAL, it can take the most difficult interrupted cuts with ease. In addition, it machines steels hardened as high as 550 Brinell faster and with less tool wear than do other carbide materials.



Modified Style 11

The unretouched photo above shows a piece of SAE 4150 steel (36 Rockwell) machined at 400 sur. ft. min. with KENNAMETAL. Despite the difficult jump cut, KENNAMETAL machined 40 of these pieces per grind, and 800 pieces per tool.

Don't compromise on design merely because of machining difficulties. Find out what KENNAMETAL can do . . . write for details.

KENNAMETAL THE All American CARBIDE

*INVENTED AND MANUFACTURED IN U. S. A.

McKENNA METALS Co.
146 LLOYD AVENUE, LATROBE, PA.
FOREIGN REPRESENTATIVES U. S. STEEL EXPORT CO
Exclusive of Canada, Great Britain and Possessions

has been associated with the company for the past six years. H. N. Arbuthnot, former Detroit branch manager, has been transferred to the Pittsburgh offices as assistant general sales manager.

◆

Associated with the Grand Rapids, Mich., plant of Haskelite Mfg. Co., Chicago, since 1931, Victor S. Barnes has been elected vice president in charge of sales.

◆

Starting in 1900 with the Crucible Steel Co., R. Edson Emery, now president of the Jessop Steel Co., Washington Pa., is celebrating his forty-second anniversary of service in the steel industry. He has been president of Jessop since 1929.

◆

Following a succession of record-breaking months, Allegheny-Ludlum Steel Corp. has again announced that the dollar value of the company's July shipments had topped all previous records. All of the total of approximately nine and a quarter million dollars went into the nation's war program, the company being 100 per cent on war production.

◆

Clyde L. Coleman has been appointed manager of the Houston, Tex., district office of American Rolling Mill Co., Middletown, O. The Dallas territory, in charge of M. B. Gebauer, will function as a sub-office within the Houston district office jurisdiction.

◆

Formerly sales engineer with Vickers Inc., Harry L. Wise has been named president and general manager of Hydraulic Machinery Inc., Detroit.

◆

With sales offices in Los Angeles, San Francisco, Fresno, Bakersfield and San Diego, Calif., as well as in Phoenix, Ariz., Victor Equipment Co. is now handling the complete line of stainless steel and alloy electrodes manufactured by Arcos Corp., Philadelphia.

◆

Election of H. B. Orr as vice president in charge of sales of Universal Products Co. Inc., Dearborn, Mich., has been announced. G. E. Dunn is chief engineer of all designs and applications of universal joints made by the company.

◆

To accept a position as assistant general manager of sales with Pittsburgh Metallurgical Co. Inc., Niagara Falls, N. Y., Paul H. Shaeffer has resigned from a similar position with Ohio Ferro-Alloys Corp. He will maintain headquarters in the general offices of the Pittsburgh Metallurgical Co. at Niagara Falls.

◆

Assistant manager of the metallurgical department since 1937, C. W. Meyers has been named special representative in the aviation field for the manufacturer's products division of the sales department, American Steel & Wire Co.

◆

Resignation of James E. Holmes as assistant sales manager of the Tubular division of the Youngstown Sheet & Tube Co. has been announced. He has become associated with D. V. Sawhill of Sharon, Pa.

MAKE YOUR OWN BLUEPRINTS
FOR LESS THAN
1c PER SQ. FOOT

Don't give your money to outside firms for blueprints. With a Simplex Mercury Vapor-Tube Portable Blueprinter you can now make blueprints in your own office at a fraction of regular commercial prices. Can be used for any of the Special Developing Processes. Operates silently. Your office girl can easily operate a Simplex. Makes continuous prints up to 42" wide. Model D (one mercury vapor lamp) has printing speed up to 24" per minute. Model E (2 mercury vapor lamps) has printing speed up to 48" per minute.

FREE TRIAL

FREE TRIAL! Don't take our word for the money-saving advantages of a Simplex! For a limited time only we will ship a regulation, complete Simplex Blueprinter on 30 days' free trial. Satisfaction guaranteed or money refunded. Write today for complete facts about this amazing money-saving offer.

WICKES BROTHERS • SAGINAW, MICHIGAN
514 NORTH WATER STREET

RELIANCE V*S DRIVE

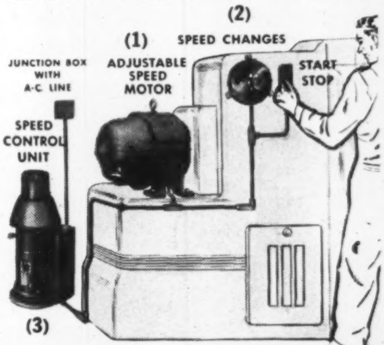
AN ALL-ELECTRIC ADJUSTABLE-SPEED DRIVE
for A-C. CIRCUITS
Speed Ranges up to 16 to 1
Sizes—1 to 30 hp.

1. DIRECT DRIVE. You need fewer parts (no intermediate speed-adjusting device) and less space. Streamline your machine design. Get your power closer to where your power is needed.

2. SPEED CONTROL CONVENIENCE WITHOUT LIMITATIONS. Start-stop button and speed-changer go at any handy point to which you can run a wire. . . . Control is within easy reach.

3. FROM A. C. POWER SUPPLY. You enjoy many advantages at a new low price due to the "packaged" V*S Speed Control Unit. Mount it anywhere. Connect it by three wires to a 3-phase a-c. circuit.

Other production aids: Quick stopping, reversing, speed-setting, safe speeds for threading, ample starting torque with smooth acceleration.



Reliance Bulletin No. 310 will give you the details

RELIANCE ELECTRIC & ENGINEERING CO.
1088 IVANHOE ROAD • CLEVELAND, OHIO
Sales Offices in Principal Cities

WE MUST WIN THIS WAR

To win the war—and the peace that follows—we must maintain efficient production in all industrial plants. Every man-hour and every machine-hour counts!

Garlock continues to make packings, gaskets and oil seals which give long, dependable service. They help industry maintain full production schedules.

GARLOCK

THE GARLOCK PACKING CO.
PALMYRA, N. Y.
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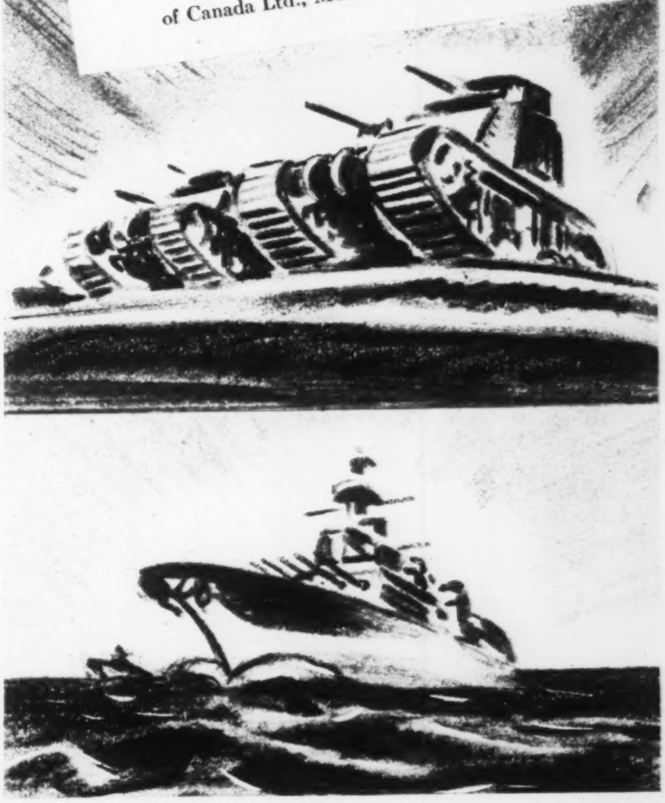
The Garlock Packing Co.
of Canada Ltd., Montreal, Que.



WHAT IS THE 4th DIMENSION in Springs ?

— those hard-to-dig-out factors which insure our giving you ... not merely the spring you ordered ... but the PERFORMANCE you WANT.

LEE SPRING CO., INC.
30 MAIN ST., BROOKLYN, N. Y.

Ask About SCIENTECH Spring Service

Play Safe WITH "BUFFALO WIRE" WINDOW GUARDS

.... The Recognized Standard of Highest Quality

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Regardless of your window sizes, shapes or types--all can be fitted with "Buffalo Wire" window guards. Superior and economical square diamond mesh fabric, square mesh wire cloth or conventional diamond mesh on rod, angle iron or channel frames. Built for stationary or swing-open installations. Also, fabrics in rolls for manufacture of guards.

Play Safe
BUFFALO
WIRE WINDOW GUARDS

Complete Information in New Window Guard Folder No. 592-AM. Write for your FREE COPY.

MADE BY THE MANUFACTURERS OF INDUSTRY'S FINEST WIRE CLOTH

Buffalo WIRE WORKS CO., INC.
ESTABLISHED 1869 AS SCHEELER'S SONS

430 TERRACE BUFFALO, N. Y.

Meetings and Expositions

September 9-11—

American Institute of Electrical Engineers. Pacific coast convention to be held at Vancouver, B. C. H. H. Henline, 33 West Thirty-ninth street, New York, is secretary.

September 11-17—

American Chemical Society. Semiannual meeting to be held at Statler Hotel, Buffalo. Dr. Charles L. Parsons, 1155 Sixteenth street, Washington, D. C., is secretary.

September 16-18—

National Petroleum association. Annual meeting to be held at The Traymore hotel, Atlantic City. Mrs. M. C. Mallon, 930 Munsey building, Washington, D. C., is secretary.

September 22-24—

Association of Iron and Steel Engineers. Annual meeting to be held in Pittsburgh. J. L. Miller, Empire building, Pittsburgh, is secretary.

September 30-October 2—

American Society of Mechanical Engineers. Joint meeting of A.S.M.E. Fuels and the A.I.M.E. Coal division at Hotel Statler, St. Louis.

October 7-10—

Electrochemical Society Inc. Fall meeting to be held in Detroit. Colin G. Fink, 3000 Broadway, New York, is secretary.

October 9—

Gray Iron Founders' Society Inc. Annual meeting to be held at Hotel Cleveland, Cleveland. W. W. Rose, 1719 K street, Washington, D. C., is executive vice president.

October 12-14—

American Society of Mechanical Engineers. Fall meeting to be held at Hotel Sagamore, Rochester, N. Y. C. E. Davies, 29 West Thirty-ninth street, New York, is secretary.

October 12-16—

American Institute of Mining and Metallurgical Engineers. Annual meeting to be held at Statler hotel, Cleveland. Frank T. Sisco, 29 West Thirty-ninth street, New York, is secretary of the Metals Division.

October 12-16—

American Society for Metals. Twenty-fourth National Metal Congress and Exposition to be held at the Cleveland Public Auditorium, Cleveland. W. H. Eisenman, 7301 Euclid avenue, Cleveland, is secretary.

October 12-16—

American Welding Society. Annual meeting to be held at Hotel Cleveland, Cleveland. Miss M. M. Kelly, 33 West Thirty-ninth street, New York, is secretary.

October 14-16—

American Institute of Electrical Engineers. Middle Eastern District meeting to be held at Pittsburgh. H. H. Henline, 33 West Thirty-ninth street, New York, is secretary.

October 16-17—

American Society of Tool Engineers Inc. Tenth semiannual meeting to be held at Springfield, Mass. Clyde L. Hause, 3567 West Grand boulevard, Detroit, is national secretary.

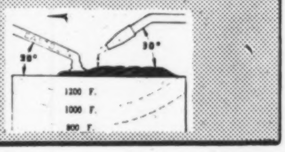
October 26-30—

National Electrical Manufacturers association. Annual meeting to be held at the Waldorf-Astoria hotel, New York. W. J. Donald, 155 East Forty-fourth street, New York, is managing director.

October 27-29—

National Safety Council. Annual meeting to be held at the Sherman hotel, Chicago. N. H. Dearborn, 20 North Wacker drive, Chicago, is managing director.

Castolin Eutectic
LOW TEMPERATURE WELDING



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36 PAGE BOOK GIVES

6

ECONOMY TIPS FOR WAR PLANTS

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1. War Production
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3. Welding Dissimilar Metals
4. Production and Salvaging of Tools
5. Salvaging Defective Castings
6. Salvaging Equipment and Machinery

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DESIGN simplification is just one reason why well known plants the country over have standardized on Castolin Eutectic Alloys. Its greater strength makes possible savings in materials and labor. With Castolin Eutectic Low Temperature Welding, it is possible in many cases, to eliminate lap or sleeve joints using, instead, and with safety — butt joints. Why not investigate the possibilities of Castolin Eutectic Low Temperature Welding today?

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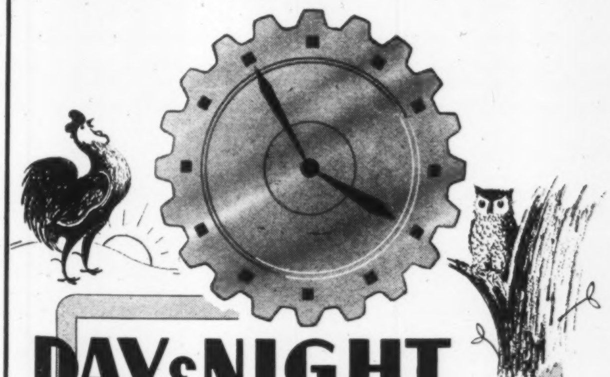
EUTECTIC WELDING ALLOYS CO.
40 Worth St. New York, N. Y.

SOME TERRITORIES AVAILABLE FOR MANUFACTURERS REPRESENTATIVES

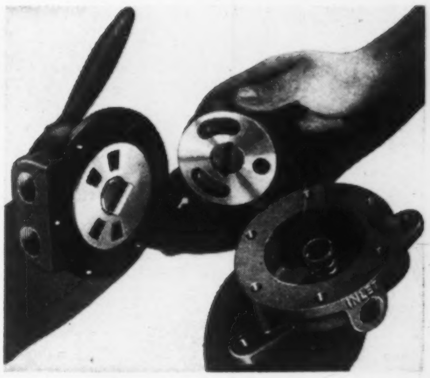


DAY & NIGHT
'round the clock

For many months the Cincinnati Gear Co. has consistently worked 'round the clock . . . day and night, producing custom-made gears . . . to fit the job.

In this race against time, more and more companies manufacturing precision equipment have selected Cincinnati Gears for their production. They demand the accuracy with precision that are symbolized in GEARS—GOOD GEARS ONLY.

THE CINCINNATI GEAR COMPANY
"Gears . . . Good Gears Only"
1825 Reading Road • Cincinnati, Ohio



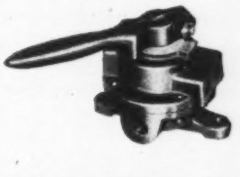
Choose...
from this complete line . . .

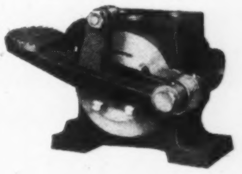
The advantages of positive, accurate control of air operated equipment are available for any type of application, for Hannifin Valves offer a complete range of choice in hand or foot operated models, adaptable to any air control need.

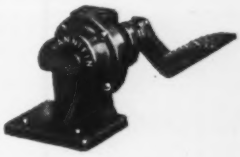
All types have the Hannifin disc-type design—no packing and no leakage or packing maintenance troubles. The bronze disc that controls air flow is ground and lapped to form a perfect seal with the seat, which is similarly finished. Wear is negligible, yet if necessary after long service, a simple relapping restores the original efficient seal.

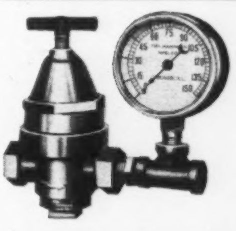
Hannifin Valves are made in 3-way and 4-way types for various standard cycles of control of single or double acting cylinders. Available in the following models: standard hand control valves; duplex valves for control of two double-acting cylinders; spring return for instant reversal upon release of foot pedal or hand lever; heavy duty rotary valves; foot operated treadle valves; electric models for remote control; manifold type for control of several units; pressure regulating valves.

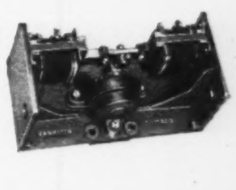
Write for Bulletin 57-MD with complete data on all types.











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HANNIFIN
"PACKLESS" AIR CONTROL VALVES